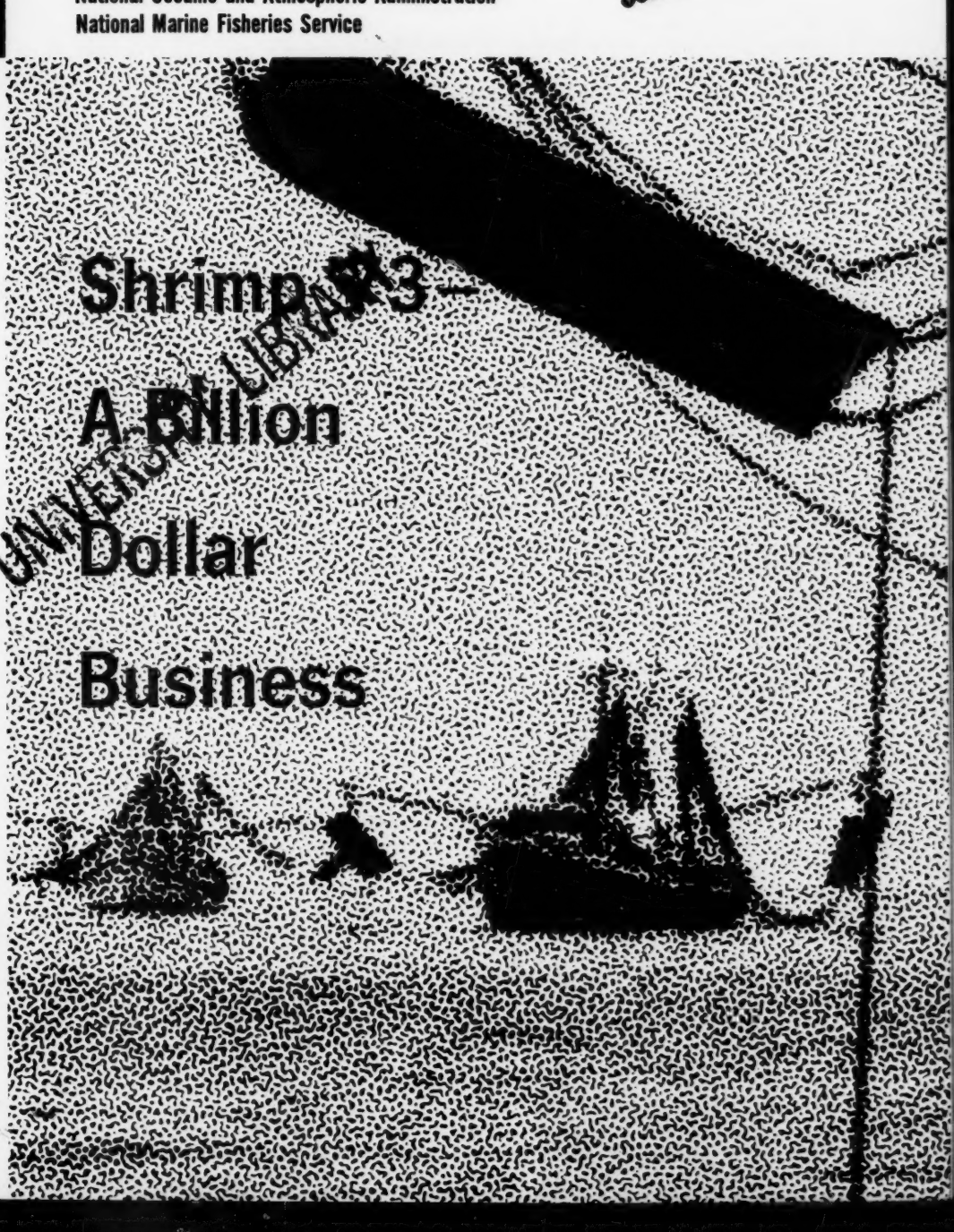
A UNITED STATES DEPARTMENT OF COMMERCE PUBLICATION

Marine Fisheries REVIEW

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service



March-April 1973
Vol. 35, Nos. 3-4
Seattle, WA

Marine Fisheries Review

Vol. 35, Nos. 3-4

March-April 1973

CONTENTS

Cover.—Section of photograph (indicated) of Gulf of Mexico shrimp trawlers.

U.S. DEPARTMENT OF COMMERCE
Frederick B. Dent, Secretary

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
Robert M. White, Administrator

National Marine Fisheries Service
Philip M. Roedel, Director

Address correspondence to: Marine Fisheries Review, NMFS Scientific Publications Staff, Room 450, 1107 N.E. 45th St., Seattle, WA 98105.

The Secretary of Commerce has determined that the publication of this periodical is necessary in the transaction of public business required by law of this Department. Use of funds for printing this periodical has been approved by the Director of the Office of Management and Budget through May 31, 1973.

Editor: Thomas A. Manar

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. Price $1.25 (single copy). Subscription price: $12.50 a year; $15.75 a year for foreign mailing.

MFR REPRINT 963

From time to time, a number of Marine Fisheries Review *will be devoted largely to a single topic. In this number it is shrimp—a whale of a business.*

Shrimp '73—A Billion Dollar Business

PHILIP M. ROEDEL

Philip M. Roedel is Director of NOAA's National Marine Fisheries Service (NMFS). This article is excerpted from a talk he gave at the 14th Annual Louisiana Shrimp Association Convention, New Orleans, La.

It is a pleasure to visit the "heart" of the shrimp country and to meet with the Louisiana Shrimp Association. It is equally enjoyable to spend some time with one of the expanding, healthy segments of the seafood industry. In Washington we tend to be concerned mainly with the ills of the seafood industry and the international aspects which affect it. It was quite refreshing to look over the facts and figures on the shrimp industry. They are impressive, and I want to relate some of them to you today. Needless to say, all our 1972 data are preliminary estimates at this time. So let's take a look at the strong points and a couple of weak points in the shrimp market last year, and speculate on possible developments for this year.

The one word that most often chacterizes any shrimp year is "record" and 1972 was no exception. There were record landings, record imports, record sales, and a record carryover was left in cold storage to start the new year.

Let's look at landings first—234 million pounds, heads off, or about 1 million pounds over the 1971 high.

Even though Louisiana showed a decrease, here in the South you were able to squeeze out another 2 million pounds over the 1971 record. The catch in the South Atlantic States was off last year, but the Gulf States more than compensated for that drop.

The Louisiana catch was about 53 million pounds. White shrimp were off, and Louisiana's landings were down 5 million pounds as a result. Texas fared better. A 7-million-pound increase there made Texas the leading producer last year, a position Louisiana had held for the previous three years.

Northern shrimp, both Atlantic and Pacific, had another good year with 79 million pounds, heads off—6 million higher than the year before. For the past three years, northern shrimp has made up about a third of the total U.S. shrimp catch.

In New England, the catch was about the same as a year ago, and it appears that the catch has stabilized at 9 or 10 million pounds in Maine, and 4 or 5 million pounds in Massachusetts. Alaska was down for the first time in many years. A prolonged water shortage cut sharply into Kodiak's production. The shrimpers did not go after the quota allowed because the water shortage made it impossible to process it. The quota is set annually by the Alaska Department of Fish and Game. Future increases in Alaska production will probably have to come from areas beyond those fantastic shrimp beds near Kodiak, which have accounted for most of the State's production. Washington-Oregon-California had a great year. Production tripled, and more than compensated for the decline in Alaska.

How did the fisherman and the vessel owner fare in 1972? Our first estimate is that the total catch was worth $195 million—17 percent over the previous year. Even with a 5 or 6 percent increase in vessel operating costs, it appears the primary producer netted about 10 percent more last year. Our estimate breaks down to $185 million for southern shrimp and $9 million for northern shrimp—a 95 and 5 percent split, which is about the same as in recent years. I am sure many of you recall that it was in 1967 that shrimp became our first $100 million fishery.

The preliminary totals for shrimp imports reached 223.2 million pounds, heads-off, which is an increase of about 8 million pounds over 1971, but a drop of 30 million pounds from the record high of 1970. I want to get into imports and the international aspects more when we take a look ahead.

Here in the Gulf States, the canned pack again topped 2 million cases, despite the relatively poor fall crop of white shrimp. In recent years, the Gulf pack has consistently been around 2 million cases while the pack in the Pacific Northwest and Alaska has been a little over 1 million. We have had a 50 percent increase in total canned shrimp production over the last 6 or 7 years. Apparently this has moved into the market with little disruption. Prices have not weakened, and I don't think there have been any serious inventory buildups.

Our first estimate of total shrimp consumption for 1972 is 420 million pounds heads off. This represents a 24 million pound or 6 percent increase over 1971. It also averages 1,150,000 pounds of raw headless shrimp per day. The total breaks down into 380 million pounds for fresh and frozen—a 21 million pound increase, and 40 million pounds for canned shrimp—a 3 million increase. On a per capita basis, it is slightly over 2 pounds per year.

SHRIMP CATCH BY REGION.

(Heads-off Weight)

Region	1969	1970	1971	1972 (est.)
	Million Pounds			
New England	16.0	13.3	13.9	14.0
South Atlantic	17.6	13.1	17.7	16.3
Gulf	125.3	145.1	141.8	143.7
Pacific	35.6	53.0	60.1	60.4
Total	194.5	224.5	233.5	234.1

Now let's put some dollar signs on these quantities. Frozen seafoods were worth $1.5 billion in 1971, and frozen shrimp accounted for half of these sales. There can be no better proof of the growing demand for shrimp than the fact that the American consumer has been averaging 5 percent more consumption each year, and willing to pay 6 percent more for shrimp.

We in NMFS do not publish data on the final value of shrimp sales; however, I think we can work through some fairly reasonable estimates. Bear with me as I throw some figures at you. I found these estimates startling, and I wonder if you gentlemen are fully aware of the real value of the shrimp industry.

Every year *Quick Frozen Foods* magazine estimates the value of retail and institutional sales of frozen shrimp. The estimate was $743 million in 1971.

Based on an increase in the quantity sold and higher prices, we estimate a 16 percent increase in the value of frozen shrimp sales. This would equal $855 million for 1972.

We estimate consumption of canned shrimp at 18 million pounds at a retail price of $2.50 per pound, with a value of another $45 million. Our guess on fresh shrimp sales is about $5 million. If my mathematics are correct, so far we have a total value of $875 million for domestic shrimp sales, frozen, canned and fresh. Add in exports and we get a grand total of $955 million.

I will make a prediction here today that in 1973 the shrimp industry is going to go substantially beyond $1 billion in sales.

If you add in all the allied activities: trawler construction, maintenance, repairs, supplies, equipment and gear, expenditures overseas, the industry may well already have arrived at the $1 billion level.

I repeat—no fishery in the United States or anywhere in the world can match the performance and sales of your industry when it comes to value.

After painting this rosy picture, I should point out two areas of concern to me in 1973 and the years beyond. One is on the domestic side of the business and the other deals with the international competition in the world shrimp market.

First, breaded shrimp sales have been at 100 to 105 million pounds for several years. Neither the retail nor the institutional market has been able to get off the current plateau. It seems to me the industry needs to take another look at its marketing strategies and merchandising techniques if it wants breaded shrimp to break out of this 100-million-pound level. Let's look for new products, new uses, new and better marketing techniques.

Second is the intense international competition for shrimp. World shrimp catches are now nearing their maximum according to best available estimates of world shrimp production. It is conceivable that by the end of this decade—or shortly thereafter—world consumption will be equal to the maximum catches that can be attained.

A decade ago Japan realized that her domestic production would not be able to satisfy her growing demand for shrimp. Japan relaxed her import restrictions, and we all know the fantastic increases that have taken place. As in the United States, Japan's imports now exceed her domestic production. By the mid-1960's, Japan had embarked on an aggressive program of establishing joint ventures in shrimping all over the world. These are really beginning to pay off now, as evidenced by the tremendous quantities of shrimp flowing to Japan. In the past 18 months, Japan has probably been over-supplied with shrimp, but they have certainly laid the foundations of a continuing supply for the years to come.

A recent development in Tokyo involves a proposed request for a $20 million increase in the Japanese Fishery Agency budget in 1973, along with an additional $30 million credit fund. With these funds, they propose to set up an International Fisheries Cooperative Agency whose objectives are to:

1. Assist the Government in concluding fishery agreements in foreign countries;
2. Promote overseas fisheries cooperation with various countries;
3. Send Japanese fisheries experts overseas when necessary; and
4. Assist the Japanese fishing industry in concluding fisheries agreements in foreign countries.

This indicates to me that you are going to be faced with even stiffer Japanese competition in the years ahead.

Besides the United States and Japan, who account for half of the world's shrimp consumption, the other large trading area is western Europe. The population of the Common Market is now higher than that of the United States, and its combined economy is about 80 percent of the United States. Thus the Common Market represents a formidable competitor with the United States in the world shrimp market. I hope we are preparing for the challenges we face in the years ahead.

The possibility of shrimp harvests leveling-off in the next decade, while demand continues to climb, is quite real. Such shortages in natural supplies will force increasing attention to mariculture. As prices increase, the development and use of higher cost methods will be stimulated.

Shrimp mariculture, if commercially developed, may appear on the surface to many of you to be a threat. But, in the long run, it may turn out to be a blessing in disguise because it could help you to better meet the rapidly increasing demand, and thus prevent the pricing of shrimp products out of the market.

MFR Reprint 963. From Marine Fisheries Review, *Vol. 35, Nos. 3/4. Copies of this reprint, in limited numbers, are available from D83, Technical Information Division, Environmental Science Information Center, NOAA, Washington, DC 20235.*

The butcher, the baker, the candlestick maker— that seems to be the answer to the question...

Who Eats Shrimp?

Citizens of the United States ate over 400 million pounds of shrimp in 1972.

What sort of people were they? Were they young, old; rich, poor; residents of the coastal states or of the mountains and plains?

Some clues can be found in a publication issued by NMFS in 1971. It is "Regional and other related aspects of shellfish consumption: some preliminary findings from the 1969 consumer panel survey," by NMFS staff members Morton M. Miller and Darrel A. Nash. Their report was issued as Circular 361 in June, 1971. The original edition is, unfortunately, out of print, but reproduced copies can be obtained from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22151, either in microfiche or hard-copy form. The original data upon which the paper was based appeared as NMFS Data Reports 58, 59, 60, 61, and 62, also published in 1971. They also are available from NTIS.

The data were collected by a market-survey firm under contract with NMFS.

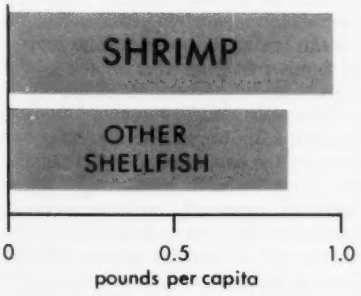


Figure 1.—Survey panel members consumed more shrimp per capita than they did of all other shellfish combined. The figures (from Miller and Nash, Appendix 2) are: Shrimp, 0.976 pound per capita; oysters, 0.210; crabs, 0.166; lobster, 0.167; lobster tails, 0.134; clams, 0.074; scallops, 0.085; and others, 0.008.

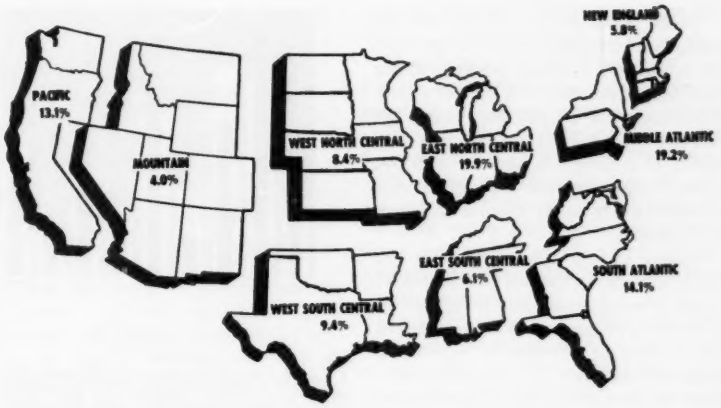


Figure 2.—Geographical divisions used in consumer panel survey. The divisions are those used by the Department of Commerce, Bureau of the Census. The percentages are those of the survey sample. (From Miller and Nash, Appendix 1.)

About 1,500 households across the land were enlisted to log the details of their seafood purchases for a 12-month period, February 1969 to January 1970. The families were carefully chosen to reflect in age, economic status, and other characteristics the whole U.S. population.

"The survey panel may be considered closely representative of the populations of U.S. households with respect to the significant demographic variables," say Miller and Nash. "Household surveys, however, are particularly vulnerable to nonsampling errors arising from unavoidable biases in the questionnaire and in the memories of the respondents."

SHRIMP—KING OF SHELLFISH

It is obvious from the data that shrimp is widely popular in the United States. Members of the survey panel ate a little more shrimp at home than they did of all other shellfish combined (see Figure 1).

REGIONAL PATTERNS

Although the study as a whole dealt with a variety of seafoods, in their Circular Miller and Nash confined themselves to shellfish purchases. Using the geographical division of the Bureau of the Census (see Figure 2), they found that shrimp products, marketed mostly frozen, have a fairly even distribution among the regions of the United States, although the bulk of the U.S. shrimp catch is, of course, taken in the Gulf states. The U.S. per capita at-home consumption of shrimp was slightly under a pound.

The per capita at-home consumption for the nine regions is shown in Figure 3. Curiously, considering their distance from the ocean, the Mountain States rank highest, though only by hundredths of a pound. And only the West North Central states (the Dakotas, Wisconsin, etc.) ate less than half a pound per capita.

"With a single exception," say Miller and Nash, "no region's per capita consumption of shrimp eaten at home varies more than 32 percent from the national average (see Figure 3). Four regions are above average in per capita consumption; one is approximately average; and four are below average.

"The Middle Atlantic States account for 24 percent of the total at-home consumption and rank first in this respect. Per capita consumption in the Middle Atlantic States is about 29 percent above the national average. The South Atlantic States follow in total consumption with 19 percent of the total, and the East North Central States are third with 15 percent of the total.

"In the South Atlantic States, the per capita consumption is about 28 percent above the U.S. average, whereas in the East North Central States the per capita consumption is 26 percent below the national average. Shrimp are also consumed in quantity in the West South Central States. In that area, per capita consumption tops the national average by 30 percent.

"Heavy shrimp consumption in the South Atlantic and South Central States is indicative of the tendency for seafood products to be consumed largely in their area of catch. Shrimp, though, lend themselves to preservation and packaging techniques that assure quality maintenance in long-distance shipping. Thus, there is an effective nationwide marketing network for shrimp products. The Mountain area States, for example, have a high per capita rate of consumption, although they are located at relatively long distances from the producing areas.

"The universality of shrimp consumption indicates little need for concentrated market development strategies. By the same token, the firmly entrenched competitive position of shrimp throughout the regions of the United States is a factor to be taken into account in the marketing of other seafoods. In any event, the geographic distribution pattern of shrimp consumption illustrates the favorable possibilities for seafoods that are suitably processed and packaged to undergo long-distance distribution."

CONSUMPTION AND INCOME

The survey showed that on the whole the better-off households ate more shellfish per capita. "Consumer panel households in the $10,000 plus income bracket, for example, consumed 38 percent of the shrimp tallied in the survey, although the group comprised only 31 percent of the total number of households. Similarly, the upper income group consumed well above their proportional share of other shellfish, with the exception of oysters. Apparently the income-consumption relationship for oysters is the reverse of what was observed for other shellfish. About 48 percent of the oysters were consumed in survey households with incomes under $7,000; this group made up 44 percent of the total

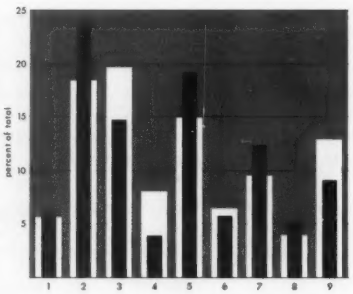


Figure 3.—Regional distribution of shrimp consumption (black) at home and population (white), 1969. Regions: 1, New England; 2, Middle Atlantic; 3, East North Central; 4, West North Central; 5, South Atlantic; 6, East South Central; 7, West South Central; 8, Mountain; 9, Pacific. (From Miller and Nash, Figure 11.)

number of households. The deviation exhibited by oysters is likely influenced by the geographic distribution of oyster consumption...oysters are heavily consumed in areas where they are produced. Family incomes in these areas generally are below national averages."

It should be noted, however, that the per capita shrimp consumption between income groups was over a fairly small range; that is, the well-to-do did not eat immensely larger quantities per capita (Figure 4). The same situation did not obtain with clams, for example, where households earning more than $7,000 consumed about three times as much clams per capita as did the less prosperous.

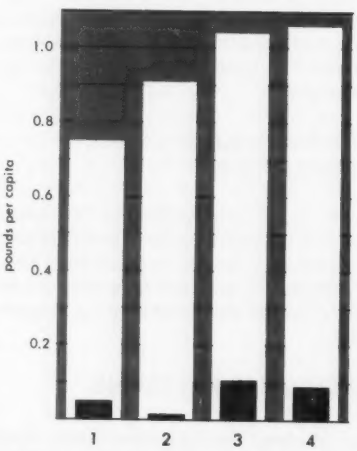


Figure 4.—Per capita consumption of clams (black) and shrimp (white), by family income. Family income: 1, under $5,000; 2, $5,000-6,999; 3, $7,000-9,999; 4, $10,000 and over. (From Miller and Nash, Figure 18.)

AGE AND CONSUMER PREFERENCE

Shrimp differed from the other seafoods studied in that there were no sharply marked differences in preference by age group (Table 1).

Table 1.—Percentage distribution of seafood consumption at home by age of household head.[1]

	Age of household head		
	Under 35	35-44	45 and over
U.S. population ..	28%	22%	50%
Percent of total consumption:			
Shrimp	31	18	51
Oysters	20	8	72
Crabs	22	19	59
Lobsters	20	21	59
Clams	14	18	68
Scallops	13	17	70
Finfish	23	18	59
Canned fish	22	20	58

[1] Projected U.S. distribution based on per household consumption revealed in survey sample. (From Miller and Nash, Table 3).

"There were positive indications in the survey that older consumers are the more disposed toward consumption of fishery products. About 50 percent of households in the United States are headed by persons 45 years and older, yet this group, according to the survey, accounts for 72 percent of the oyster consumption, 68 percent of the clam consumption, and 70 percent of the scallop consumption, to cite several examples. On the other hand, the 28 percent of U.S. households headed by persons under 35 appear to consume only 20 percent of the oysters, 14 percent of the clams, and 13 percent of the scallops. Shrimp alone, among seven categories of seafood examined, exhibited an even distribution with respect to age of household head.

"Income may be a factor in the tendency for "older" households to consume more fishery products, assuming that higher incomes are associated with

older household heads. Nonetheless, the apparent even distribution of shrimp would seem to discount this contention. The simple conclusion thus is that young households are not consuming their proportional share of seafood products. Consequently, there is a generation of consumers growing up who are not developing the preferences for seafood products exhibited by persons in the older age brackets. In brief, the lines of tradition in seafood consumption are being broken. Producers would do well, therefore, to pay heed to this apparent trend and direct their marketing efforts accordingly."

After its publication, the Miller-Nash study was criticized on technical statistical grounds which indicated that some of the findings, notably the proportions between the amounts of seafoods eaten at home and consumed outside the homes might be subject to substantial errors, and that authors have admitted that the criticisms may have merit. No one, however, has objected to the principal conclusions, and those answer the question that is the title of this article. Who eats shrimp? The answer, according to the survey, seems to be—just about everybody: the young, the old, the rich, the poor, people who live in the shrimping ports of the Gulf and those who are a lot more familiar with roping cattle than catching marine fish.

These conclusions should not be misconstrued to suggest that shrimp plays any large part in the diets of the households sampled, of course. If one assumed that the 1,500 housewives visited the supermarket once a week, then they had 78,000 opportunities to purchase fresh or frozen shrimp. They did so only 2,575 times: on the average, only 3.3 percent of the time did their weekly shopping list include shrimp. That means less than twice a year. (They paid, in 1969, a nostalgic average of $1.35 a pound for the shrimp they bought.)

The universality of the appeal of shrimp, however, as indicated by Miller and Nash, has been borne out, of course, by increasingly higher consumption figures since 1969, the year of the survey.

T.A.M.

Shellfish Shells Salvaged For Commercial Use

The shells of shellfish, long considered waste by the seafood industry, are being salvaged to produce a cellulose-like substance of commercial value to a variety of industries.

Chitin (pronounced "kite-n") and its derivative, chitosan, are being produced at a small pilot plant on the outskirts of Seattle, Washington, and offered to researchers who have already identified scores of known and potential uses for the product, according to the Commerce Department's National Oceanic and Atmospheric Administration. Some of the uses of chitin and chitosan are:

As a papermaking additive to improve the wet-strength properties of newsprint (the paper on which newspapers are published) and other paper;
As an additive to baby food formulations;
As a coagulant in the treatment of water supplies, sewage, and waste water;
As an additive to stomach antiacids;
In the treatment of wounds;
For controlled, long-term release of herbicides and insecticides;
In textile finishes;
In water-base paint emulsions;
As a new synthetic fiber;
As a food thickener;
In the manufacture of films; and
In the manufacture of specialty adhesives.

The chitin-chitosan plant, operated by Food, Chemical, and Research Laboratories, Inc., of Seattle, was built in response to growing demands for alternate methods for the disposal of the thousands of tons of lobster, shrimp, and crab carcasses annually dumped in ocean and near-shore regions, a pollution problem as such material is highly resistant to biodegradation. In many areas, small seafood processors may be forced out of business as environmental regulations prohibit the dumping of untreated shellfish wastes into coastal waters.

Recognizing that this situation threatens the existence of an important segment of the food industry, NOAA's Office of Sea Grant provided support to a research program at the University of Washington and sought other ways to develop economically sound ways of utilizing waste products from marine food processing plants. The chitin-chitosan program is an important part of this venture.

Basically, chitin is the structural material that holds together the shells of crustacea such as crab, shrimp, lobster, and crayfish. (Other arthropods synthesize this polymer as an important component of their exoskeleton, too. Most of the 800,000 known insect species, in fact, rely upon chitin to give them structural support and protection from the environment.)

At the Seattle plant, the leg shells of Alaskan King Crabs and local Dungeness Crab are processed for chitin. This process is linked to another process which produces fish protein concentrate. This sister process, developed through the University of Washington Sea Grant Program, complements the chitin process and vice-versa, extracting the protein from the residues and leaving a dry shell. Together, the processes totally utilize fish and shell wastes introduced to the plant.

Operating at full capacity, the plant can produce about a ton of chitin each month. Food, Chemical, and Research Laboratories, Inc., is considering a second, larger plant.

NOAA has guaranteed the pilot plant a market by purchasing $48,000 worth of chitin and chitosan during 1972-1974. These materials are distributed for the Sea Grant Program through the Oceanographic Institute of Washington on request to researchers throughout the country who are studying the uses of chitin and chitosan in new products and markets.

The pilot plant in Seattle, according to NOAA officials, may be the prototype for a fledgling chitin/chitosan industry, providing a practical and profitable use for the 75 to 83 percent "waste" found in most species of shellfish.

Source: U.S. Department of Commerce News, NOAA 73-14.

Shrimp Imports in 1972 Total 223.2 Million Pounds

Preliminary figures on shrimp imports to the United States during calendar year 1972 show that 69 nations, including the People's Republic of China, contributed to the 223.2 million pound total.

The statistics, provided to the NMFS Statistics and Market News Division by the Department of Commerce, Bureau of the Census document an increase of 16.7 percent over imports for 1971. The 1972 value is estimated at just over a quarter of a billion dollars.

Mexico led all other countries with more than 80 million pounds. India was second with more than 33 million pounds. These countries accounted for just under half of all U.S. shrimp imports. Imports from the People's Republic of China were small—81,304 pounds.

Countries, and totals in thousands of pounds, were:

1	Australia	1,490.7
2	New Guinea	6.2
3	Indonesia	2,440.9
4	Singapore	417.8
5	Malaysia	2,993.7
6	Philippines	525.7
7	Thailand	3,978.5
8	Hong Kong	452.8
9	Republic of China	6,021.2
10	Japan	728.4
11	Republic of Korea	56.0
12	People's Republic of China	81.3
13	Canada	657.0
14	Greenland	117.6
15	Iceland	23.1
16	Norway	13.7
17	Sweden	398.8
18	Denmark	76.3
19	United Kingdom	131.1
20	Netherlands	55.8
21	Austria	3.8
22	Turkey	7.5
23	Spain	514.6
24	Bangladesh	733.2
25	India	33,523.5
26	Sri Lamka	489.4
27	Pakistan	2,636.3
28	Iran	1,307.6
29	Lebanon	14.2
30	Jordan	30.0
31	Kuwait	2,295.3
32	Bahrain	746.2
33	Qatar	58.6
34	South Yemen	13.7
35	Saudi Arabia	441.6
36	Ethiopia	43.1
37	Kenya	0.6
38	Mozambique	33.2
39	Malagasy Republic	431.2
40	Republic of South Africa	481.2
41	Cameroon	581.0
42	Ivory Coast	50.6
43	Liberia	767.5
44	Senegal	98.5
45	Argentina	206.9
46	Chile	226.3
47	Paraguay	46.0
48	Brazil	8,931.4
49	Peru	903.7
50	Ecuador	6,935.4
51	Colombia	5,979.2
52	Venezuela	7,994.6
53	Guyana	6,905.7
54	Surinam	2,132.6
55	French Guiana	3,621.7
56	Trinidad	1,311.4
57	Dominican Republic	20.9
58	Haiti	12.2
59	Jamaica	6.6
60	Bahamas	9.8
61	Canal Zone	130.4
62	Panama	10,104.5
63	Costa Rica	1,829.3
64	Nicaragua	6,605.2
65	Honduras	4,810.6
66	El Salvador	5,734.8
67	Guatemala	2,091.5
68	British Honduras	25.7
69	Mexico	80,681.5

MFR REPRINT 964

After peaking in the 1940's, then suffering a sharp decline in the 1950's, New England's shrimp fishery has increased rapidly as...

European Demand Helps Spur New England Shrimp Catches

JOHN R. KALLIO

After an upsurge in the 1940's (Maine landings of northern shrimp in 1945 totaled 580,000 pounds) and subsequent rapid decline, the fishery for northern shrimp was revitalized in the early 1960's in Maine and Massachusetts (Table 1).

In 1961 67,000 pounds were landed with a value of $14,000. Landings increased year by year, reaching a peak in 1969 of 28.3 million pounds valued at 3.5 million dollars. Although landings dropped during the next three years, the value of the catch averaged about 4.7 million dollars for 1970-1972. Ex-vessel prices have ranged from a low of 9.5 cents a pound in the early 1960's to a high of 32 cents in the winter of 1972. Fishing grounds ranged from Stellwagen Bank to Mt. Desert Island off of Bar Harbor.

MASSACHUSETTS

Almost all of the landings of northern shrimp are at Gloucester although small amounts are landed at Provincetown. Landings at Gloucester were very light until 1969 when the inshore fleet entered the fishery. Landings in 1969 increased greatly to nearly 4 million pounds and Gloucester found a replacement for the dwindling whiting resource.

In 1970, with increased fishing effort, landings increased to almost 6.5 million pounds valued at 1.2 million dollars. Landings were down slightly in 1971 but increased in 1972 not only because of increased fishing effort but also due to an apparent increase in the availability of the resource. Landings in 1972 totaled 8.2 million pounds valued at 1.4 million dollars.

There is only one processing plant in Gloucester that processes in any volume. Nearly 80 percent of the Gloucester landings is trucked to plants in Maine for processing. Labor costs are relatively low there, allowing Maine firms to sell the finished product at a lower price than if the shrimp had been processed in Gloucester. A good percentage of the finished product is exported to Europe.

Table 1.—New England Shrimp catch, 1962-72. Quantities (heads-on) in thousands of pounds; value in thousands of dollars.

Year	Maine		New Hampshire		Massachusetts		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1962	352	51	—	—	—	—	352	51
1963	538	64	—	—	23	3	561	67
1964	925	112	—	—	7	1	932	113
1965	2,075	243	—	—	18	2	2,093	245
1966	3,831	542	40	4	23	3	3,894	549
1967	6,925	865	44	5	22	2	6,991	931
1968	14,363	1,590	95	10	114	11	14,572	1,611
1969	24,235	3,045	128	15	3,908	418	28,271	3,478
1970	17,004	3,512	120	19	6,398	1,167	23,522	4,698
1971	18,419	3,671	112	18	6,005	964	24,536	4,653
[1]1972	16,587	3,232	230	41	8,212	1,424	25,029	4,697

[1] Preliminary

The three principal fishing grounds are Stellwagen Bank, Ipswich Bay, and Jeffreys Ledge.

NEW HAMPSHIRE

Landings in New Hampshire are small, although increasing slightly each year. There are only a few small boats in this fishery and several land their catches at Maine ports. Principal fishing grounds are the Isle of Shoals and Jeffreys Ledge.

MAINE

George Kern, owner of the Eastern Fish Company and a fish market in Portland, was one of the persons principally responsible for the revitalization of this fishery. In the early 1960's he encouraged several boats to go shrimping. The catches were sold in his market in the shell and some were peeled in his plant. He had a contract with a firm in Georgia that bought his surplus supplies. The Georgia plant sent a large trailer truck up to Portland nearly every week. Of course, there was no European market at this time.

Landings increased every year as more vessels entered the fishery and more processing plants were set up to process shrimp. The landings nearly doubled between 1966 and 1967 as the European market was developed. Landings reached a peak in 1969 with over 24 million pounds valued at over 3

John R. Kallio is a member of the Statistics and Market News Division, NMFS Northeast Region, Gloucester, Mass.

million dollars to the fishermen. This fishery was developed during the years when the inshore fleet was beginning to feel the effects of the dwindling whiting resource.

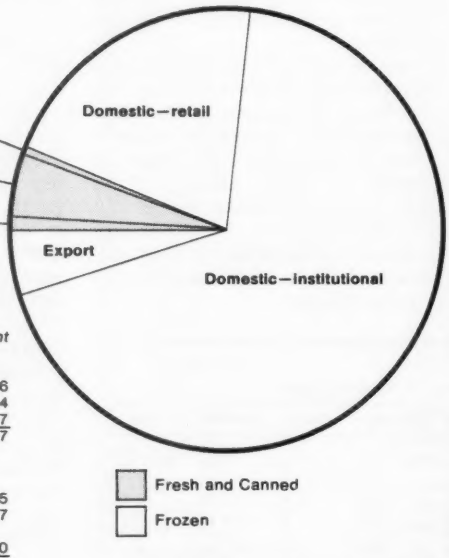
For several years in the middle 1960's, some boats used propane gas cookers to cook the shrimp at sea. After a few years, this practice was abandoned. Boats that were landing the raw product were making more than the boats cooking. It was not profitable to buy cookers, tanks of propane gas, lose about 20 percent in weight from cooking, buy salt, and put on an extra man to cook the shrimp.

The two major ports for landings are Portland and Boothbay Harbor. The first peeling machine was installed at the Marine Biological Supply Corp. in East Harpswell and the second machine at the Central Wharf Fish Plant in Portland. These companies exported some of their finished product to England as prawn. The foreign market was developed with the assistance of the Market Research and Services Division, NMFS. These plants were also the first to establish an IQF line for freezing shrimp. Automatic peelers were necessary because of the small size of the shrimp and a shortage of help.

The grounds principally fished are located between Jeffreys Ledge off of New Hampshire to Mt. Desert Island off of Bar Harbor, Maine.

MFR Reprint 964. From Marine Fisheries Review, *Vol. 35, Nos. 3-4. Copies of this reprint, in limited numbers, are available from D83, Technical Information Division, Environmental Science Information Center, NOAA, Washington, DC 20235.*

The Shrimp Dollar, 1972



	$ Million	Percent
Frozen		
Domestic Trade		
Retail	198	20.6
Institutional	657	68.4
Export Trade	45	4.7
	900	93.7
Fresh and Canned		
Domestic Trade		
Fresh	5	0.5
Canned	45	4.7
Export Trade		
Canned	10	1.0
	60	6.2
	960	99.9

The U.S. shrimp industry is fast approaching the billion dollar mark in sales. The dollar value of final sales in 1972 is estimated at $960 million. Frozen shrimp dominates sales. Most frozen shrimp goes to the institutional market (restaurants and other food service outlets). As the frozen shrimp market has expanded, fresh shrimp sales have accounted for a smaller share of the total market. Most canned shrimp is sold at retail, and sales have increased in recent years because of rising production in Alaska. The export trade in shrimp is significant and accounts for 45 to 50 percent of the total value of edible seafood exports exported by the United States.

Donald R. Whitaker, Staff Economist, Fishery Products and Inspection Division, NMFS

MFR REPRINT 965

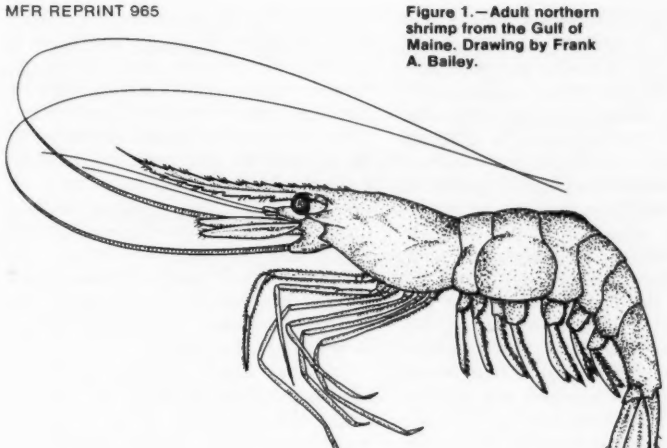


Figure 1.—Adult northern shrimp from the Gulf of Maine. Drawing by Frank A. Bailey.

Biologically, the northern shrimp differs drastically from the southern shrimp which makes up most of the U.S. catch.

Fishery for Northern Shrimp, *Pandalus borealis,* in the Gulf of Maine

ROLAND L. WIGLEY

ABSTRACT

A fishery for northern shrimp in the Gulf of Maine has grown rapidly during the last decade to become one of the most valuable fisheries in New England. American landings of this shrimp in the period 1962 to 1972 increased from 388,000 pounds to 24,295,000 pounds; correspondingly, value increased from $57,000 to $4,557,000. Trends in the total catch of northern shrimp in the past few years, plus decreased catch per unit effort during the past year, indicate that maximum utilization of this stock was attained in 1969. This paper briefly reviews the history and development of the fishery, landings, vessel types and gear, processing, and recent development in the fishery.

INTRODUCTION

Northern shrimp, *Pandalus borealis,* (Figure 1) is a medium-sized species that is commercially abundant in North Pacific and North Atlantic waters. This species has supported a small fishery along the southern Maine coast for several decades and during the last decade it has developed into one of the most valuable fisheries in New England. Vessels from Maine, New Hampshire, and Massachusetts landed a total of 24 million pounds of northern shrimp in 1969. This fishery started as an off-season fill-in for herring and lobster fishermen. Today it is a major species fished throughout the year. Expansion of this fishing occurred at a time when other fisheries in New England were declining. It has generated a need for new processing plants, new boats, and has substantially increased employment. Maine has been the traditional center of this fishery and remains so today.

NOTES ON BIOLOGY

Some of the more important biological characteristics of the northern shrimp's life cycle are diametrically opposite to those of the southern commercial shrimp (genus *Panaeus*).

Southern shrimp *(Penaeus)* spawn in offshore waters; the eggs are broadcast free into the sea where they drift, without parental care until they hatch. Average number of eggs per clutch is 500,000 to 1,000,000. They begin life as male or female and complete their life cycle without change. Young stages migrate to the bayous and other estuarine areas where they pass their early life. When they attain moderately large size they migrate to offshore waters and spawn. Life span of most species of penaeid shrimp is roughly one year.

Northern shrimp spawn in offshore waters and attach the eggs to the pleopods where they are protected until they hatch. Average number of eggs per clutch is 800 to 3,400. They are protandric hermaphrodites, functioning first as males. Larval stages develop in coastal waters. Juvenile and young adult stages move to offshore waters as they grow larger. When they become egg-bearing females they migrate to coastal waters during the egg maturation period. Life span of northern shrimp in the Gulf of Maine is four to five years.

Northern shrimp is a cold-water species that occurs in commercial abundance in northern regions of both the North Pacific and North Atlantic Oceans. In the North Pacific it is fished commercially in continental shelf waters of both the Asiatic and North American continents. In the North Atlantic it is fished in many areas, such as the Barents Sea, off Scandinavia, British Isles, Ice-

Roland L. Wigley is a scientist on the staff of the NMFS Northeast Fisheries Center, Woods Hole, Mass.

land, southern Greenland, Newfoundland, and the Canadian Maritimes. The Gulf of Maine population is the southernmost stock of this species. This stock also ranks among the first in terms of growth rate for this species.

In the Gulf of Maine it occurs in commercial abundance in the Bay of Fundy region and along much of the western Gulf of Maine southward to Cape Cod, Massachusetts, and the northern margin of Georges Bank. It is less common in the eastern and southeastern sections of the Gulf.

HISTORY

Although fishing for northern shrimp in the Gulf of Maine has produced substantial quantities only in recent years, 1963 to present, this species was known to inhabit Gulf waters since 1873. In those early years most ocean fishing was pursued by hook-and-line and the species sought were groundfishes, such as the cod, haddock, halibut, and hake. Shrimp would normally go unnoticed, except possibly as a food item in stomachs of groundfish. However, with the advent of beam trawls and other trawls, around the turn of the century, shrimp were caught, but only in small quantities, owing to the large size mesh used for groundfish.

Prior to 1927, small draggers operating out of Gloucester, Massachusetts, caught and landed modest quantities of northern shrimp from time to time. General Seafoods Corp. took an interest in the commercial utilization of this species. It sponsored several exploratory cruises in 1927 and one in 1928, with the objective of locating a sufficiently large and dependable supply of shrimp. Mediocre results, combined with more promising prospects in other fisheries, deterred further development in the shrimp industry at that time.

The next major investigation of shrimp in the Gulf of Maine took place in 1936. A Norwegian fishery expert, Johan Hjort, who was instrumental in getting a shrimp fishery started in his homeland, visited the United States at the request of American scientists and supervised a series of exploratory shrimp-trawling cruises in the western Gulf of Maine. Principal area of operation was Jeffrey's Basin and the region east of Cape Ann, Massachusetts. This work was conducted aboard the research vessel *Atlantis,* in cooperation with the Woods Hole Oceanographic Institution. Results indicated that *Pandalus* was most abundant in the same general area where General Seafoods' vessels found them. These explorations were followed by a cooperative venture financially supported by the U. S. Bureau of Fisheries, the Federated Fishing Boats of New England and New York, Inc., and the Fishermen's Relief Corporation of Portland, Maine. A fishing vessel, *New Dawn,* was outfitted and, again, demonstrated that shrimp fishing off New England was feasible. In spite of the fact that commercially profitable catches of shrimp were made during these explorations—catches equal to or surpassing those in Norway and Sweden—two more years passed before the beginning of a new fishery materialized.

In 1938 the first large-scale fishing for northern shrimp began in southern Maine. That year 13 vessels that ranged in size from 46 to 73 feet began dragging for shrimp and landing their catches at Portland. Fishing was conducted primarily off Wood Island, located southwest of Cape Elizabeth. Catches were made only during the early spring months (February to April); all trips were of 1-day duration. Part of the catch was sold fresh, but most of it was frozen for future use. In the summer of 1938 an attempt was made by the Maine Department of Sea and Shore Fisheries and the U. S. Bureau of Fisheries to learn if a year-round fishery could be established. Two small fishing boats carried out explorations along the Maine coast in July and August. Results were generally unsatisfactory and it was concluded that shrimp fishing during summer months along that part of the Maine coast were unprofitable.

During the years 1939 to 1942 small amounts of shrimp were landed, the supply substantially greater than the demand by local consumers. Customarily fishermen would fish for a few hours or a day and devote the next few days to selling the catch in neighboring towns. Occasionally the shrimp could not be sold and had to be discarded.

In 1942 there was increased demand for fresh shrimp for immediate consumption and home-canning. Furthermore, a major outlet opened when a commercial cannery at Friendship, Maine, began packing shrimp. Shortly thereafter other processors began canning and freezing whole shrimp and shrimp tails. By 1944 sufficient demand had developed that processors took all northern shrimp that could be landed. From that time up to the present, shrimp supply has governed the fishery. As catches increased more and more boats entered the fishery. Conversely, as catches diminished some of the boats switched to other species.

Principal American ports at which northern shrimp are landed are: Gloucester, Massachusetts; Portland, Boothbay Harbor, New Harbor, Rockland, Vinalhaven, and Southwest Harbor, Maine (Figure 2).

Annual landings and ex-vessel values of northern shrimp at U. S. ports since 1938, when this fishery started, are listed in Table 1 and illustrated in Figure 3. The most striking fact revealed by these data is the dramatic increase in

Table 1.—Annual landings and ex-vessel values of northern shrimp at American ports during the years 1938 to 1972. (Weight in thousands of pounds, value in thousands of dollars.)

Year	Weight Landed	Value
1938	106	7
1939	54	2
1940	9	0.5
1941	0	0
1942	111	4
1943	295	15
1944	462	21
1945	582	29
1946	166	9
1947	194	11
1948	27	3
1949	10	2
1950	8	2
1951	58	10
1952	104	18
1953	38	7
1954	0	0
1955	0	0
1956	0	0
1957	0	0
1958	5	2
1959	17	5
1960	90	20
1961	68	14
1962	388	57
1963	561	67
1964	932	113
1965	2,093	245
1966	3,894	550
1967	6,991	872
1968	14,572	1,612
1969	28,271	3,478
1970	23,522	4,697
1971	24,684	4,650
1972	24,295	4,557

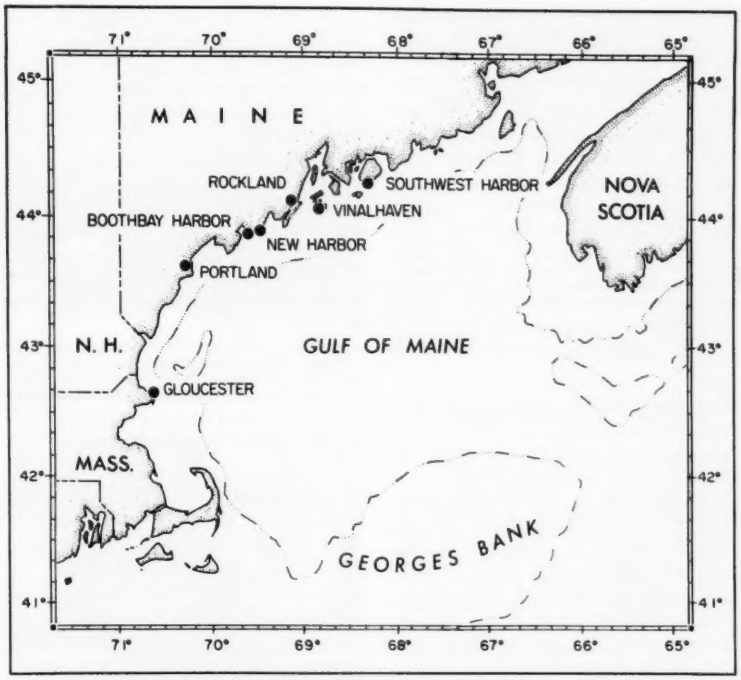


Figure 2.—Gulf of Maine region showing some of the principal shrimp-landing ports of New England.

landings that began in 1962-1965 period and reached a peak of 28 million pounds in 1969. Concurrently several fin fisheries (sea herring, silver hake, haddock) were declining; thus there were vessels and crews available that could quickly convert from finfishing to shrimping. Also noteworthy are the four years 1954-1957 during which no shrimp were landed, even though substantial demand existed throughout the entire period. The smaller total catch during the past three years suggests that the approximate maximum harvest of this stock has been attained. The rapidity with which this fishery was established attests to the demand for shrimp by the consumer.

TRENDS IN ABUNDANCE

Trends in the actual abundance of the Gulf of Maine shrimp stock may be judged from changes in catch per unit of effort. A comparison of the number of pounds of shrimp landed by the same group of vessels on a per-trip basis over a period of years provides an index of abundance. A "trip" for small or medium shrimp boats operating in coastal Maine waters has traditionally been one day of fishing. In Table 2 are listed the fishing effort and landings for the fleet operating in the vicinity of Portland, Maine. The number of pounds of shrimp caught per trip averaged over a 1-year period is the index of abundance. These data are based on Market News Service reports issued by the U. S. Bureau of Commercial Fisheries, as summarized and reported by Apollonio and Dunton (1969). Although there may be some complicating factors negating the validity of these types of data, because of the so-called "learning factor", improvements in fishing gear, etc., it is the best information available that reveals trends in abundance of this stock. Also, the possible complications appear to be minor in comparison to the substantial changes in catch.

Catch rates in 1964 averaged 1,128 pounds per trip, based on 189 fishing trips. During the subsequent four years the fishing effort and catch rate increased rather steadily each year. In 1968 the catch rate averaged 3,661 pounds per trip, based on 914 trips. One of the more interesting aspects of this catch-effort trend is the increased catch rate in the face of enormous increases in total landings. Total landings increased from 213,210 pounds in 1964 to 3,346,500 pounds in 1968. The substantially larger catches per unit effort each year during the time period evaluated, in spite of a continually mounting increase in total effort and removals, is sound evidence of marked increases in abundance of shrimp.

SIZE OF SHRIMP

In the early years of the Gulf of Maine shrimp fishery only the large egg-bearing females were caught. These are the oldest and largest members of the population, usually egg-bearing females that migrate into coastal waters during the

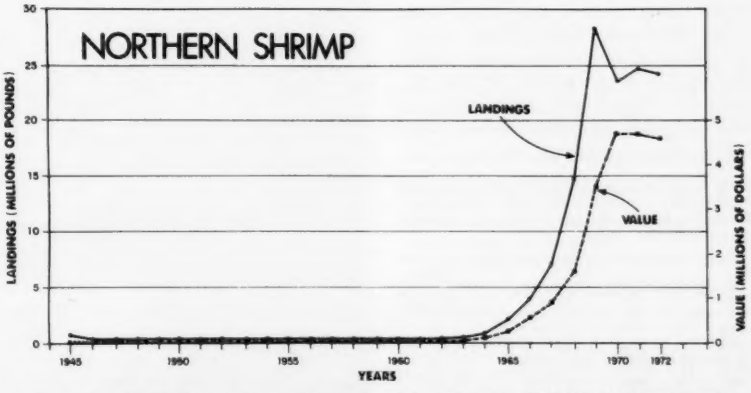


Figure 3.—U.S. landings and value of northern shrimp from the Gulf of Maine, 1945 to 1972.

final stages of the egg maturation period. They generally range in size (total length: as measured from the tip of the rostrum to posterior end of the telson) from 4¾ inches to 7½ inches. Average length, which of course varies according to season, location, etc., is approximately 6 inches. Average weight of a whole shrimp is slightly less than ½ an ounce.

Shrimp landed in more recent years are believed to have been significantly smaller than those taken in earlier years of the fishery (as described above). Changes in the geographical areas fished in recent years could account for part of the size change. Smaller shrimp of saleable size, that is the male and transitional-stage shrimp (as well as females) inhabit deeper, offshore parts of the Gulf of Maine. Now that larger vessels are engaged in shrimping there is a strong likelihood that smaller shrimp are caught, some of which are landed. Other changes in fishing practices, such as the use of smaller mesh nets, smaller cull size, year-round fishing, could result in the catching and utilization of smaller shrimp.

VESSELS

Vessels currently engaged in the Gulf of Maine shrimp fishery include a rather wide variety of styles and sizes. Inasmuch as the fishery started as a small off-season enterprise, it is to be expected that the vessels used would be those used in other fisheries. Most vessels engaged in this fishery during its developmental stages (and still in use) were lobster boats. Characteristically, the Maine lobster boat is a wooden vessel in the 30-40 foot length class having the wheelhouse approximately amidship and an open cockpit aft. Modifications of these boats for shrimping were, in some cases, very modest. Minimal changes required the use of the pot-hauler for hauling in the shrimp net. Other lobster boats were more elaborately modified with a winch, gantry or gallows frames, or large boom, etc., for side trawling or stern trawling. An example of a modified lobster boat is shown in Figure 4. Customarily, all small and moderately small vessels make daily excursions to the fishing grounds and return to port in the afternoon with the catch. Only the larger, offshore vessels stay at sea for several days at a time.

Another common type of vessel engaged in shrimping is the small or medium-size trawler (dragger), such as those shown in Figure 5. These are side trawlers that were formerly used in the whiting fishery or for other groundfish species. Commonly they are wooden vessels 50 to 75 feet long and operated by a crew of three or four men. They required virtually no modifications for shrimp fishing.

In recent years some specialized vessels have joined the fleet; a few were constructed specifically for Gulf of Maine shrimping. In addition, several Gulf of Mexico shrimp trawlers have been brought to New England. They are characterized by their broad beam, large boom, and a wheelhouse located well forward. One or two Gulf of Mexico shrimpers have retained their outriggers that permit trawling with two nets simultaneously. Some of the newer vessels also have cooking, chilling, or freezing facilities aboard.

For detailed information on shrimp vessels, the reader is referred to the several articles in the publications sponsored by the Federal-Provincial Atlantic Fisheries Committee (1971).

FISHING GEAR

The otter trawl is the standard gear used in the northern shrimp fishery in the Gulf of Maine. Several sizes and styles of trawls are in common usage, depending largely on the vessel size, the experience of the crew with specific nets and their results, type of bottom on the fishing grounds, and other related factors. One of the most commonly used nets is the "50-70 trawl". This is a standard New England 2-seam trawl having a 50-foot headrope and a 70-foot groundrope. Larger or smaller versions of this net are used, but the 20-foot

Table 2.—Annual estimates of catch per unit effort based on shrimp landings at Portland, Maine, from 1964 through 1968 (from Apollonio and Dunton, 1969).

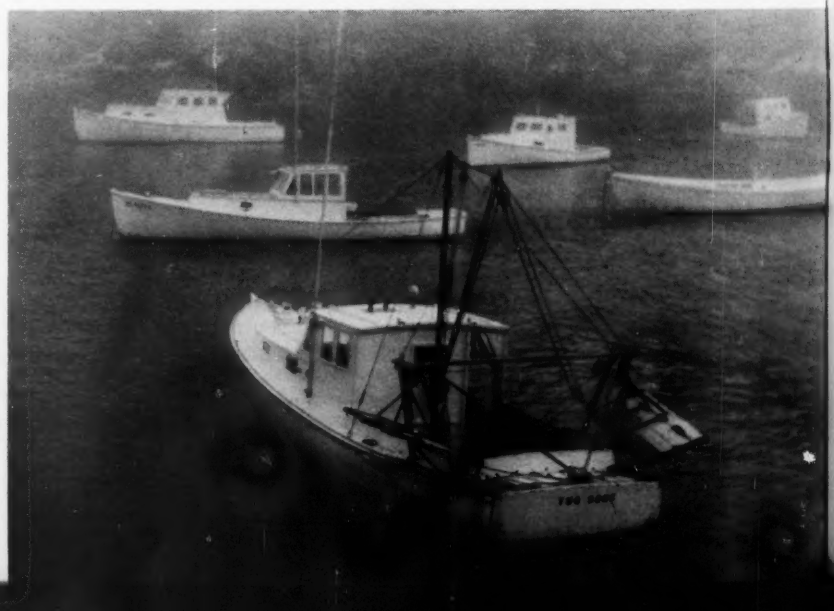
Year	Boats (no.)	Trips (no.)	Total landings (pounds)	Average landings per trip (pounds)
1964	12	189	213,210	1,128
1965	20	419	869,800	2,076
1966	31	652	1,572,600	2,412
1967	33	859	2,426,800	2,825
1968	28	914	3,346,500	3,661

Table 3.—Number of shrimp vessels in New England, listed according to state and size, for years 1964-1970 (from Bruce, 1971).

	Maine		Massachusetts		
Year	Large[1]	Small[2]	Large	Small	Total
1964	17	12	2	1	32
1965	18	16	3	1	38
1966	16	13	10	1	40
1967	44	23	21	1	89
1968[3]	—	—	—	—	—
1969	89	134	40	2	265
1970	96	191	46	3	336

[1] Any vessel built primarily for dragging or other fishery than inshore lobstering.
[2] Lobster boats.
[3] An accurate count of the number of vessels for 1968 is not available.

Figure 4.—Maine lobster boat modified with gallows frames and boom for stern trawling for shrimp. Photograph courtesy of Robert A. Bruce.



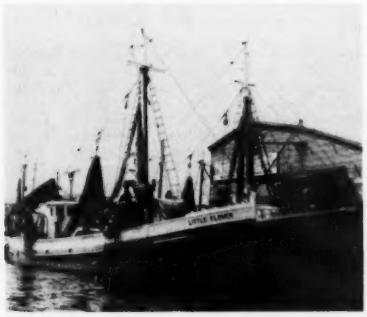


Figure 5.—Typical side trawlers used for shrimping, as well as for fishing whiting and other groundfish, in the western Gulf of Maine. Photography courtesy of Robert Bruce.

Figure 6.—Transferring shrimp from the deck to the storage hold of a medium-size shrimp trawler. Photograph courtesy of Warren J. Rathjen.

difference in headrope-footrope length is usually maintained. Netting is most often made of nylon or polyethylene of 2-inch (stretch measure) in the wings and square, 1¾ inch mesh in the codend. Rollers on the footrope are employed when fishing rough bottom areas; chain-rigged footropes are used on smooth bottoms. Rectangular otter doors 5-7 feet in length (depending on size of trawl net) and a short ground cable are customarily used.

Small vessels use a rather greater variety of styles of otter trawls. Many are modifications of fish trawls that are on hand, others are specifically designed for shrimp fishing by an individual fisherman for a particular locality or to be accommodated by a particular vessel.

Semi-balloon trawls, used for shrimping in the Gulf of Mexico, have been used. Also, the 4-seam trawl, which has an especially high headrope height, has been used successfully.

Shrimp pots, which are stationary baited traps, are relatively new to the Gulf of Maine region. Those that are being tried have various shapes and sizes, but for simplicity in construction, they are frequently rectangular in shape, have a slot for an entry-way, have an internal weight to serve as an anchor, and are constructed of wire hardware cloth. Pots are baited with fish, such as herring, and set and buoyed individually or in strings (groups). Perhaps the most promising aspect of the pot method of taking shrimp is its use in rocky, untrawlable bottoms.

PROCESSING THE CATCH

Substantial differences in size of vessels in the shrimp fleet and attendant differences in fishing procedures has created a variety of handling and processing procedures aboard ship and in the processing plants ashore. Furthermore, since some dealers and processors prefer cooked shrimp, this has added another dimension to the processing procedure. At present there are four major categories of processed shrimp with a seemingly endless number of combinations. The four categories are:

1. whole or headless
2. cooked or uncooked
3. peeled or unpeeled
4. raw or frozen

Aboard the larger vessels the catch is dumped on a sorting table where finfish, mollusks, other invertebrates, and bottom debris are removed. Generally the catch is fairly clean and does not require a large amount of work obtaining a clearly sorted catch. When the fishery was strictly a winter activity, the low temperature retarded spoilage, which eliminated the need to cook shrimp aboard ship or to pack it in ice for the short time at sea. In more recent years, as the fishing season has extended through the warm season (see Table 4), some vessels have adopted the practice of boiling whole shrimp in a brine solution. Other vessels pack raw, whole shrimp in ice, to be processed (possibly peeled, cooked or frozen) at the facilities in port. Smaller boats store the shrimp on deck without icing, when weather conditions permit. At other times they pack them in ice in wooden boxes.

Processing firms at the major shrimp ports have automatic cleaning, peeling, cooking, and freezing equipment. Firms that were engaged in processing shrimp in Maine during 1969 are listed in Table 5. For additional information pertaining to shrimp processing and marketing the reader is referred to the reports by Whitaker (1971a and 1971b).

Table 4.—United States annual landings of northern shrimp by months, 1965-1969 (from Whitaker, 1971). (weight in thousands of pounds, whole shrimp).

Month	1965	1966	1967	1968	1969
January	344	360	1,002	1,723	3,694
February	731	1,212	1,647	3,074	6,078
March	905	2,019	3,161	5,074	9,120
April	50	60	571	1,855	2,621
May	—	—	7	103	67
June	—	—	—	—	209
July	—	—	—	—	155
August	—	—	—	36	113
September	—	—	—	102	341
October	—	—	—	303	491
November	—	2	65	563	400
December	45	179	472	1,532	946

Table 5.—List of shrimp processing companies that were operating in Maine in 1969 (from Whitaker 1971).

Bath Canning—Prospect Harbor—Raw meats, raw headless
Belfast Canning Co.—Prospect Harbor—Raw meats
Windjammer Sea Farming Corp.—Eastport—Peeled, raw (canned natural)
A. M. Look Canning Co.—East Machias—Dip (canned, and natural)
Three Rivers Fish Co.—Jonesport—Raw meats
Brown Fish Company—Portland—Raw meats
Central Wharf Fisheries, Inc.—Portland—Raw meats
Eastern Fish Company—Portland—Raw meats
Mid-Central Fish Company—Portland—Raw meats, raw headless
Stinson Canning Co.—Prospect Harbor—Raw meats
F. J. O'Hara and Sons, Inc.—Rockland—Raw meats, raw headless
Royal River Packing Co.—Yarmouth—Raw meats, raw headless
Scandia Seafood Company, Inc.—Bailey Island—Cooked whole
Malpeque Shrimp, Ltd.—Boothbay Harbor—Cooked whole
Maine Biological Supply & Development Corp.—Brunswick—Raw meats
Maine Lobster Company—Portland—Raw meats
Maine Crabmeat Company—Portland—Raw meats
Gulf of Maine, Inc.—Portland—Raw meats, breaded
Paul Bayley Seafoods Company—Scarboro—Raw meats, raw headless
Port Lobster Company—Kennebunkport—Raw meats
Rockland Shrimp Corp.—Rockland—Cooked whole
Mill Cove Lobster Co. (No. 2)—Southport—Cooked whole
Atwood Brothers, Inc.—St. George—Cooked headless, raw meats
Mill Cove Lobster Co. (No. 1)—Trevett—Raw meats

RECENT TRENDS IN THE FISHERY

Some of the more important trends in the northern shrimp fishery in the Gulf of Maine pertain to the fleet and to the shrimp catch. In regard to the fleet, the trend is toward larger vessels, especially designed and equipped for shrimping. Shrimp vessels capable of operating farther offshore and during the warmer seasons of the year are becoming particularly more numerous in the fleet operating out of Gloucester, Massachusetts.

Total landings, as shown in Table 1 and Figure 3, are leveling out at roughly 24 million pounds per year. Correspondingly, the value of shrimp landings is also leveling out, at $4.5 million annually. Less well documented are decreases in catch per unit effort and an equally discouraging decrease in the size of shrimp landed.

Although the bulk of each year's landings is caught during the later winter and early spring, there is a trend of increased fishing during the warm seasons of the year (Table 4).

Assuming the future demand for shrimp remains high, it can be anticipated that small shrimp will make up a larger proportion of the catch.

REFERENCES

Apollonio, S., and E. E. Dunton. 1969. The Northern Shrimp, *Pandalus borealis*, in the Gulf of Maine. Project Completion Report, Project 3-12-R, Public Law 88-309. Department of Sea and Shore Fisheries, Fisheries Research Station, West Boothbay Harbor, Maine.

Bruce, R. A. 1971. The New England Shrimp Fishery. *In:* Proceedings, Conference on the Canadian Shrimp Fishery, p. 257-274, Can. Fish. Rept. No. 17.

Federal-Provincial Atlantic Fisheries Committee. 1971. Proceedings, Conference on the Canadian Shrimp Fishery. Canadian Fish. Rept. No. 17, May 1971, Department of Fisheries and Forestry, Ottawa, Canada, p. 1-501.

Haynes, E. B., and R. L. Wigley. 1969. Biology of the Northern Shrimp, *Pandalus borealis*, in the Gulf of Maine. Trans. Am. Fish. Soc. 98:60-76.

Scattergood, L. W. 1952. The Northern Shrimp Fishery of Maine. Comm. Fish. Rev. 14(1): 1-16.

Whitaker, D. R. 1971a. The New England Shrimp Industry. *In:* Proceedings, Conference on the Canadian Shrimp Fishery, pages 433-440, Can. Fish. Rept. No. 17.

_____1971b. Trends in the United States Shrimp Fishery. *In:* Proceedings, Conferences on the Canadian Shrimp Fishery, pages 397-425, Can. Fish. Rept. No. 17.

MFR Reprint 965. From Marine Fisheries Review, *Vol. 35, Nos. 3-4. Copies of this reprint, in limited numbers, are available from D83, Technical Information Division, Environmental Science Information Center, NOAA, Washington, DC 20235.*

Gulf Estuaries Studied

The great shrimp nursery grounds in the estuaries of the Gulf of Mexico are being described in unprecedented detail in a series of publications issued at the recommendation of the Gulf States Marine Fisheries Commission. The most recent such publication to appear is "Cooperative Gulf of Mexico Estuarine Inventory and Study, Florida: Phase I, Area Description," by J. Kneeland McNulty, William N. Lindall, Jr., and James E. Sykes. All, at the time the report was prepared, were members of the NMFS Gulf Coastal Fisheries Center Biological Laboratory, St. Petersburg Beach, Fla.

The object of the study was to develop realistic comparable appraisals of estuarine resources along the entire coast. "The planners envisioned a broad study that would include physical descriptions of the estuarine basins and waters within them plus comprehensive biological studies of plant and animal life. Funding was provided through the Commercial Fisheries Research and Development Act (Public Law 88-309, as amended) with which studies in Alabama, Mississippi, and Louisiana were financed in part." The St. Petersburg Laboratory and the Gulf Coastal Fisheries Center, Galveston, Tex., took on the preparation of the parts of the study dealing with the west coast of Florida and the Texas coast.

Published as NOAA Technical Report NMFS CIRC-368, the Florida study deals with the vegetation of the coast, its geology, stream discharge, water temperature, salinity, oysters and clams, and artificial fishing reefs. Figures and charts trace the rise in population in the area during the past decades, its economic development, and the amounts of pollution and dredging.

Florida's Gulf coast estuaries cover just over 3 million acres: half unvegetated, and half occupied by mangroves, tidal marshes and submerged vegetation. These estuaries are drowned river valleys, resulting from melting polar ice caps during the current interglacial stage.

The hydrology of the estuaries is discussed from three aspects: stream discharge, water temperature and salinity. The impact of these on commercially important oysters and clams is discussed also.

The economic development of Florida's Gulf coast has resulted in increased human population near its estuaries along with its attendant problems: artificial fishing reefs, pollution and dredging. Although dredging has come under legislative control, pollution legislation has been only partially effective and much remains to be done in this area to preserve the estuarine environment.

The report carries extensive figures and tables. The entire coast is covered by a series of detailed maps (see Figure 1).

NOAA Technical Report NMFS CIRC-368, which consists of 126 pages, is available from the Superintendent of

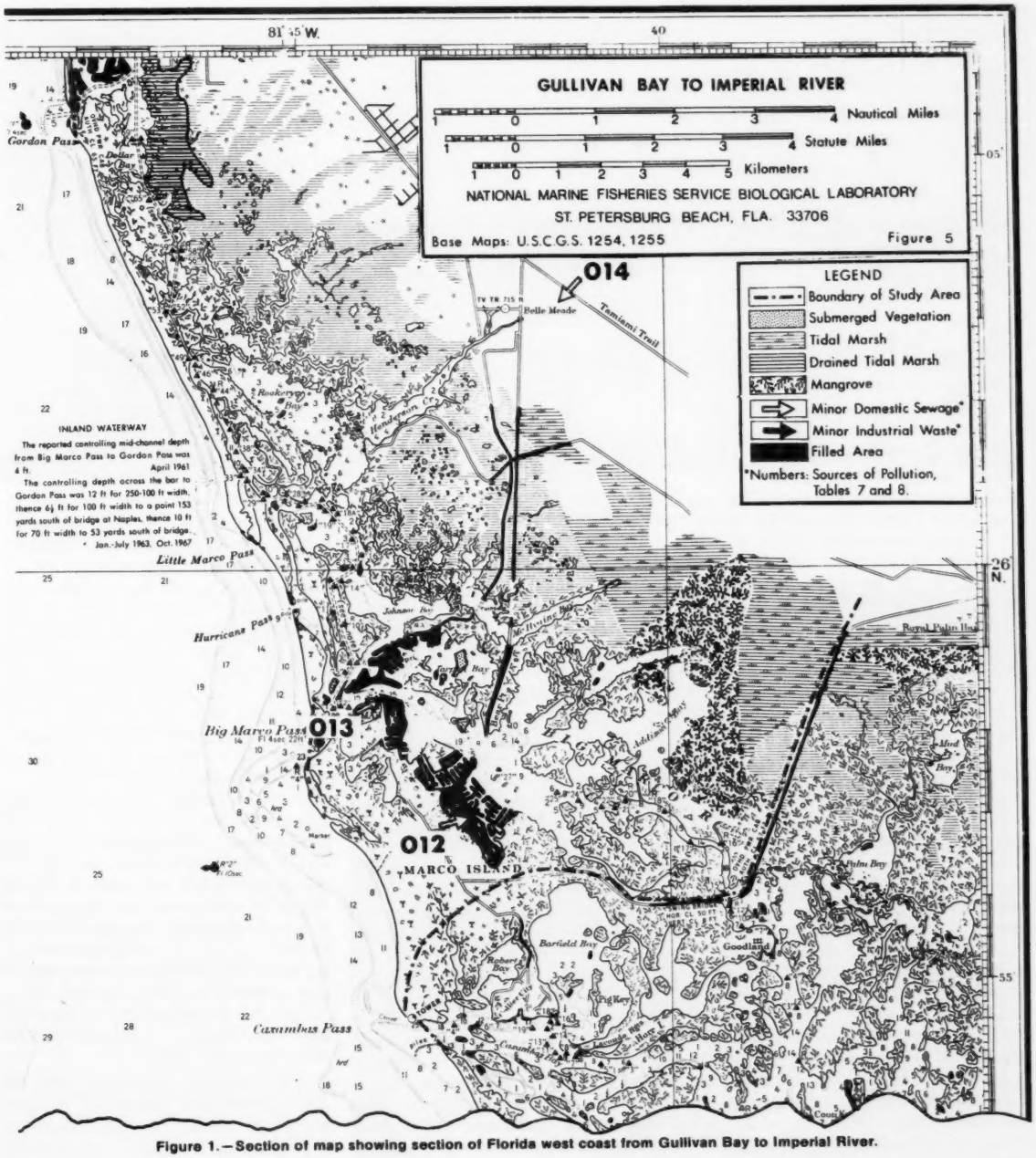


Figure 1.—Section of map showing section of Florida west coast from Gullivan Bay to Imperial River.

Documents, U.S. Government Printing Office, Washington, DC 20402. The price is $1.25.

Of the other studies, that for Alabama was published by the Alabama Conservation Department. The Louisiana study was published by the Louisiana Wild Life and Fisheries Commission.

The Mississippi and Texas reports are still in preparation. Another volume of the Florida study is also being prepared.

MFR REPRINT 966

Since 1959, the NMFS laboratory in Galveston has conducted pioneering shrimp research: today its primary emphasis in on culture and population dynamics.

Shrimp Research at the Galveston Laboratory of the Gulf Coastal Fisheries Center

ROBERT F. TEMPLE

Shrimp are today the most valuable marine species harvested from U.S. coastal waters by commercial fishermen. Of the yearly total landings, which amounted to an estimated 234.1 million pounds (heads-off) valued at $190.6 million in 1972, approximately 61 percent by volume or 87 percent by value was harvested from waters of the Gulf of Mexico. Three species of shrimp belonging to the family Penaeidae comprise the bulk of the landings from Gulf waters. They are the white *(Penaeus setiferus)*, brown (*P. aztecus*), and pink (*P. duorarum*) shrimp.

Shrimp have not always been the most sought after marine organisms by Gulf of Mexico fishermen. Over the years, oysters, mullet, and red snapper at one time or another dominated commercial landings in the expanding Gulf fishing industry. However, with the construction of larger vessels and the replacement of shrimp seines and net by the otter trawl around 1915, the shrimping industry underwent considerable expansion.

The growth of this already expanding industry was increased even more in the years that followed as new concentrations of shrimp were discovered in the Gulf. Large numbers of white shrimp were discovered off Louisiana in 1936, and concentrations of brown shrimp were found off Texas in 1947. Continued exploration revealed brown shrimp in waters off Alabama, Louisiana, and Mississippi, and in 1949 pink shrimp were discovered in high concentrations on the Tortugas grounds off the southern tip of Florida. Only one year later—1950—large numbers of brown and white shrimp were discovered on the Campeche grounds in the southwestern Gulf.

Robert F. Temple is Deputy Director of the Gulf Coastal Fisheries Center. He has been a member of the Galveston staff since 1961. **This paper is Contribution No. 364 from the NMFS Gulf Coastal Fisheries Center, Galveston Laboratory, Galveston, Tex. 77550.**

Paralleling the growth of the shrimp fishery in the Gulf of Mexico was Federal involvement in biological research. As early as 1929 a small laboratory was established at Offatts Bayou in Galveston, Texas, for the principal purpose of studying marine fisheries and particularly the ecology of oysters. Little time passed, however, before the emphasis was shifted to shrimp, and an investigation of the South Atlantic and Gulf of Mexico shrimp fishery was initiated. Headquartered in Louisiana and Georgia, research on white shrimp was carried on at several locations.

In 1950, the Galveston Laboratory (Figure 1) was established, and a cooperative study with Texas A&M University was begun on the fisheries and oceanography of the Gulf of Mexico. Several years later emphasis was placed on "red tides" that resulted in massive fish kills throughout the Gulf, and it was not until 1959 that shrimp research was reemphasized. Since that time extensive studies have been undertaken on shrimp population dynamics, life histories, and physiology and behavior with the sole purpose of promoting efficient management and utilization of this valuable natural resource. General highlights of the research completed at the Galveston Laboratory during the 1960's are as follows.

SHRIMP POPULATION DYNAMICS STUDIES

One of the primary thrusts of these studies has been mark-recapture experiments designed to provide information on shrimp movement, growth, and mortality. This information is essential to those individuals responsible for managing this natural resource. To conduct these studies, NMFS biologists caught shrimp on the fishing grounds, measured and grouped them according to length, and marked or tagged them by techniques developed in the laboratory. The shrimp were then released on the fishing grounds, and those subsequently recaptured by fishermen were returned to the biologists with information on time and place of capture. A reward was paid for the return of each shrimp.

From studies of this type, biologists have been able to determine movements of the pink shrimp in waters west of Florida (Figure 2), white shrimp along the coast of Louisiana (Figure 3), and brown shrimp along the Texas coast. Estimates of mortality and growth have also been determined, but results are highly variable, not only between species but also within a species (Table 1). Causes for the variation bebetween mortality estimates are not known, but one of several factors that are highly suspect has been the types of tags or marks used and their effects on the shrimp. Consequently, tag improvement has been a continual process throughout the years.

A second major thrust has been the development and refinement of techniques to predict the abundance of brown shrimp in offshore Texas waters (Figure 4). This work, initiated in the early 1960's, consisted of developing abundance indices of young shrimp as they enter Galveston Bay and also juvenile shrimp that enter the bait fish fishery. Analyses of this information re-

Figure 1.—The NMFS Gulf Coastal Fisheries Center Galveston Laboratory has been the focal point for biological research on shrimp stocks in the Gulf of Mexico since 1959.

vealed that the abundance indices for postlarvae and juveniles reflected the size of the offshore harvest 2 to 4 months before the shrimp moved offshore. Of considerable value to the shrimping industry, this information is now made available to interested parties as it is being collected in the form of an informational bulletin.

LIFE HISTORY STUDIES

Prior to 1960 much of the research on the life history of shrimp dealt with either juvenile shrimp in estuarine waters or adult shrimp on the offshore fishing grounds. Little was known about the distribution and abundance of the newly hatched shrimp, called larvae, in offshore waters. Consequently, early life history studies received a considerable amount of attention in the 1960's.

This work entailed systematic sampling of waters off Florida and in the northwestern Gulf of Mexico with fine mesh nets. Use of fine mesh nets was essential, for the newly hatched shrimp are microscopic, free floating, and part of the plankton. The work in Florida waters was conducted under a Bureau of Commercial Fisheries contract with the University of Miami and that in the northwestern Gulf by personnel at the Galveston Laboratory. Time-consuming and arduous, this task resulted in biologists determining the seasonal abundance and distribution of newly

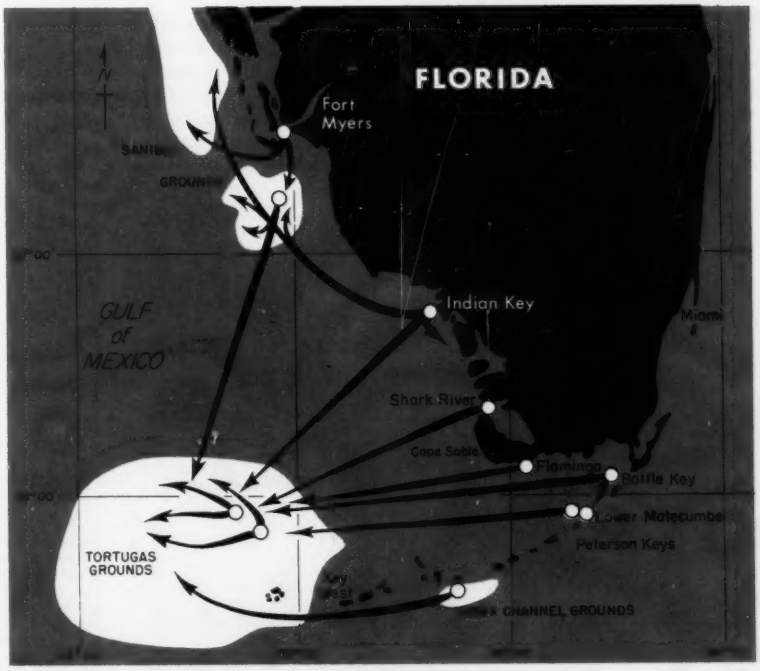


Figure 2.—The movement of pink shrimp in the waters of south Florida was documented by NMFS biologists between 1958 and 1963. Juvenile shrimp migrated as much as 150 nautical miles to the fishing grounds. The open circles show the site of the release of the marked shrimp, the arrows the possible migration routes to the recovery areas, and the tips of the arrows the point of recovery of the marked shrimp. On the east coast of Florida, all marked shrimp were found near the release site only. (Adapted from Figure 2, Costello and Allen, 1966.)

Table 1.—Weekly instantaneous rates of fishing (*F*), natural (*M*), and total mortality (*Z*), and growth (*K*) from mark-recapture studies of *Penaeus* off the southern United States (Modified from Berry, 1969).

Shrimp	*F*	*M*	*Z*	*K*	Reference
Pink (*P. duorarum*)	0.96	0.55	0.76,1.51	0.07	Kutkuhn (1966)
Pink (*P. duorarum*)	0.16-0.23	0.02-0.06	0.22-0.27	0.04-0.06	Berry (1967)
Pink (*P. duorarum*)	0.03,0.07	0.08,0.11	0.11,0.18	—	Costello and Allen (1968)
White (*P. setiferus*)	—	—	0.46	0.12	Klima (1964)
White (*P. setiferus*)	0.06-0.19	0.08	0.14-0.27	0.09[1]	Klima and Benigno (1965)
Brown (*P. aztecus*)	0.06	0.21	0.27	—	Klima (1964)

[1] Estimate of *K* not included in published material.

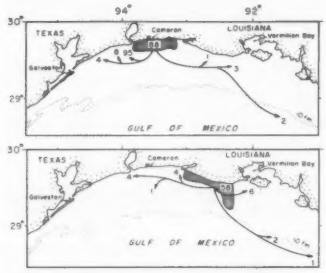


Figure 3.—Marked white shrimp released off the coast of Louisiana on September 2, 1962 moved laterally along the coast and into deeper areas. The last recovery was in March 1963. The top figure shows the movements of white shrimp released off Cameron; most of the recoveries (88) were in the Cameron area or nearby, but two shrimp moved east to south of Vermillion Bay. Of the shrimp released near Vermillion Bay (bottom figure), again most were recaptured near the point of release, but a few moved several miles away. (Adapted from Klima, 1964, Figure 3.)

hatched shrimp in the respective areas (Figures 5 and 6).

Complementing this effort were hydrographic studies designed to increase the biologist's knowledge of the environment in which the young shrimp spend the first few weeks of their life. Water temperatures were measured throughout the entire water column by bathythermographs, and salinities were recorded at preselected depths from water samples collected with Nansen bottles.

In addition, surface and bottom water currents were studied by depositing drift bottles and seabed drifters, respectively, in an attempt to learn how currents might or might not affect the movement of young shrimp from the offshore spawning grounds into the estuarine nursery areas. In southwestern Florida waters, for example, it was hypothesized from results obtained that the movement of young pink shrimp might be south off the Tortugas spawning grounds into the Florida Straits and then up the east coast and into the nursery grounds around the Florida Keys (Figure 7).

Another study closely related to life history research was an intensive examination of sediment types over the continental shelf. Samples of bottom sediments were collected systematically from an area bounded by the U.S.-Mexico border on the west and Key West, Florida, on the east. Analyses of these data revealed a marked difference between sediments in the eastern and western Gulf, and the distribution of pink shrimp in Florida waters appeared related to sediments with high organic matter (Grady, 1971).

PHYSIOLOGICAL AND BEHAVIORAL STUDIES

To complement observations made in field studies, extensive research was undertaken in the laboratory under controlled conditions to determine the physiological requirements of shrimp. Such information, although basic in nature, was of considerable value in understanding the behavior of wild shrimp.

By carefully controlled studies, biologists at the Galveston Laboratory learned that each of the three species—white, brown, and pink—responded differently to environmental factors such as salinity and temperature. In general, white shrimp preferred lower salinities, brown shrimp intermediate, and pink shrimp the higher salinities. Furthermore, it was discovered that the young of each species, i.e., postlarvae and juveniles, could tolerate a much wider range of salinities than could the older

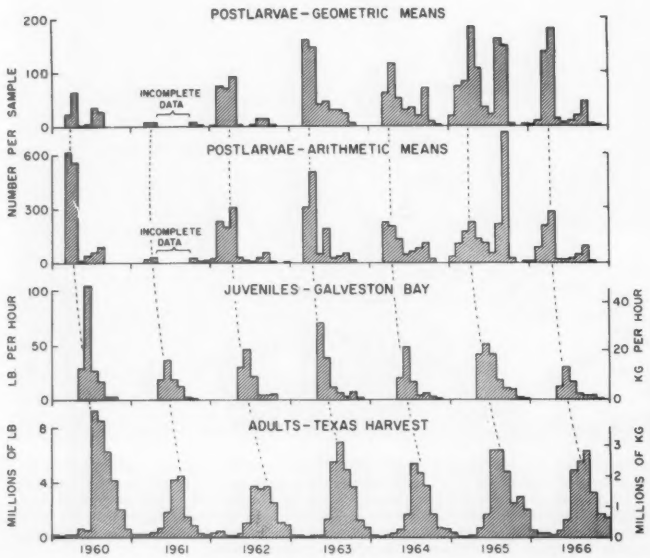


Figure 4.—The size of the brown shrimp crop harvested yearly off the Texas coast can be predicted from abundance indices of postlarvae entering Galveston Bay as well as from indices of juvenile shrimp taken in the bait fishery. This figure shows the abundance of brown shrimp at the postlarval, juvenile, and adult stages by month, 1960-66. Predictions based on postlarval indices are available to the shrimp industry 4 to 6 weeks sooner than those from the catches of juvenile shrimp. The dotted lines indicate this, by showing the time elapsing between the appearance of peak postlarval catches and high catches of adult stages. (Berry and Baxter, 1969, Figure 13.)

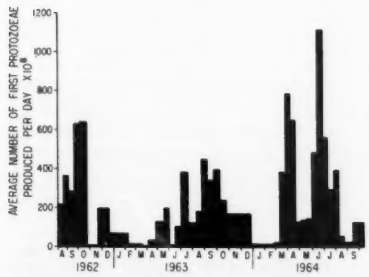


Figure 5.—Towing fine mesh nets from research vessels, personnel at the Rosenstiel School of Marine and Atmospheric Sciences, University of Miami, determined the seasonal abundance of larval (protozoeal) pink shrimp in south Florida waters. This work was completed under a Bureau of Commercial Fisheries contract negotiated through the Galveston Laboratory. At this early stage in their life history, shrimp exist in astronomical numbers. The authors estimate that the annual production on these grounds of first protozoae is on the order of 8,700 billion of the tiny creatures. (From Munro, Jones, and Dimitriou, 1968, Figure 2.)

shrimp. Salinity tolerance apparently decreased with an increase in age!

Laboratory experiments also revealed the effect temperature has on the growth of shrimp. The growth rate of both brown and white shrimp increased rapidly between 15° and 20°C, but at higher temperatures differences were noted between species. Between 20° and 25°C the growth of brown shrimp postlarvae decreased somewhat and stopped at 35°C. White shrimp, however, continued to grow rapidly, at least in temperatures as high as 32°C. This information, applied to field observations of adult shrimp, may explain why white shrimp remain in nearshore Gulf waters in the summer months during periods of high water temperature whereas brown shrimp move offshore to cooler waters.

Differences also were noted between brown and white shrimp at low water temperatures. It was clearly documented that brown shrimp postlarvae could tolerate lower temperatures than could white shrimp postlarvae. Furthermore, it was demonstrated that at 11°C, temperatures of nearshore Gulf waters during the winter, postlarvae of the brown shrimp could survive for at least 1 month yet grow very little. Lower temperatures, initiating a protective response, caused brown shrimp young to bury in the sediments. This survival at low temperatures and the burying response suggest the capability of brown shrimp spawned in fall to overwinter in nearshore waters of the Gulf before entering the estuaries in the spring.

TODAY'S RESEARCH

Over the past 4 years, research programs at the Galveston Laboratory have undergone considerable consolidation and streamlining. Today there are two major investigations, one dealing with shrimp aquaculture (see Neal, "Progress Toward Shrimp Farming in the United States," in this number) and the second with shrimp population dynamics (see Caillouet and Baxter, "Gulf of Mexico Shrimp Resource Research," in this number).

The aquaculture research actually had its origin with the early life history studies. Larval shrimp collected in fine mesh nets could not be identified. Consequently, biologists undertook the task of raising shrimp from known parents in small numbers for descriptive purposes only. As a result of this early work, interest was kindled in the possibilities of shrimp farming and today extensive studies are underway to determine the feasibility of shrimp aquaculture in the United States.

Growth of the shrimp fishing industry, although most rapid in the 1930's and 1940's, has not stopped. Within the past 10 years there has been a gradual shift to larger, more powerful shrimp trawlers capable of towing two 70-foot trawls rather than two 40-foot trawls as

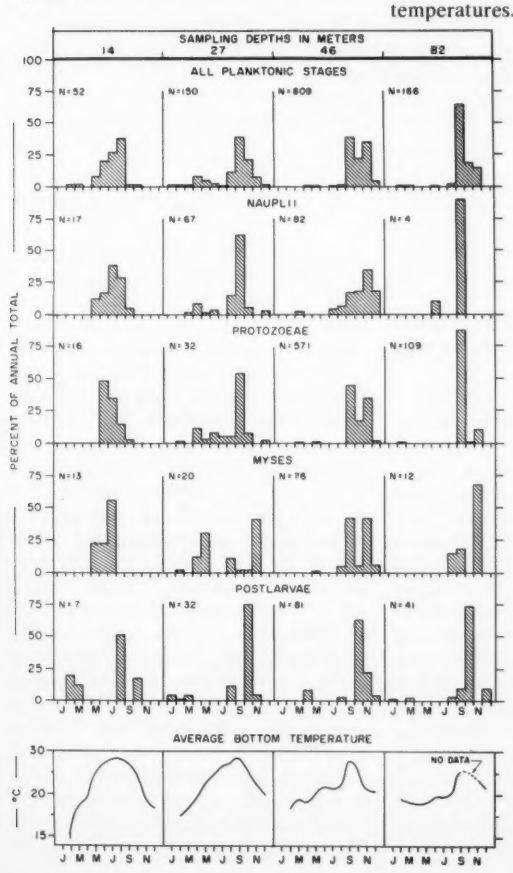


Figure 6.—The seasonal abundance trends of young or larval shrimp (*Penaeus* spp.) as related to depths and water temperatures were determined by intensive sampling of waters off the Texas coast. In general, peak abundance was attained at a progressively later time in the year with an increase in water depth. In addition, observed increases in abundance and increases in temperature of bottom waters at each depth were closely parallel, suggesting a possible direct relation. (From Temple and Fischer, 1967, Figure 4.)

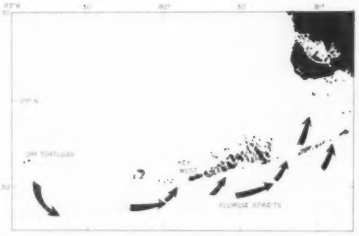


Figure 7.—Studying young or larval pink shrimp in the waters off southwestern Florida, personnel at the University of Miami, on the basis of estimates of shrimp abundance and measurements of the ocean currents, hypothesized that the young shrimp, found most plentifully near the Dry Tortugas, entered the nursery areas of south Florida waters by an indirect route (black arrows). (Adapted from Munro, Jones, and Dimitriou, 1968, Figure 10.)

in the past. Clearly the unit of effort has changed, and its effect on the shrimp populations must be clearly understood if the stocks are to be managed properly. As a result, shrimp population dynamic research, i.e., studies on shrimp fishing and natural mortality, movement, and growth, have been reinitiated at the Galveston Laboratory.

LITERATURE CITED

Berry, Richard J. 1970. Shrimp mortality rates derived from fishery statistics. Gulf Caribb. Fish. Inst., Proc. 22d Annu. Sess., p. 66-78.

Berry, Richard J., and Kenneth N. Baxter. 1969. Predicting brown shrimp abundance in the northwestern Gulf of Mexico. FAO (Food Agr. Organ. U.N.) Fish. Rep. 57, 3:775-798.

Costello, T. J., and Donald M. Allen. 1965. Migrations and geographic distribution of pink shrimp, *Penaeus duorarum*, of the Tortugas and Sanibel Grounds, Florida. U.S. Fish. Wildl. Serv., Fish Bull. 65:449-459.

Grady, John R. 1971. The distribution of sediment properties and shrimp catch on two shrimping grounds on the continental shelf of the Gulf of Mexico. Gulf Caribb. Fish. Inst., Proc. 23d Annu. Sess., p. 139-148.

Grady, John R. 1972. Environmental Research. *In* Report of the National Marine Fisheries Service, Gulf Coastal Fisheries Center, Fiscal Years 1970 and 1971. NOAA Technical Memorandum NMFS Ser-1, p. 15-20.

Klima, Edward F. 1964. Mark-recapture experiments with brown and white shrimp in the northern Gulf of Mexico. Gulf Caribb. Fish. Inst., Proc. 16th Annu. Sess., p. 52-64.

Munro, J. L., A. C. Jones, and D. Dimitriou. 1968. Abundance and distribution of the larvae of the pink shrimp *(Penaeus duorarum)* on the Tortugas Shelf of Florida, August 1962-October 1964. U.S. Fish Wildl. Serv., Fish. Bull., 67(1):165-181.

Temple, Robert F., and Clarence C. Fischer. 1967. Seasonal distribution and relative abundance of planktonic-stage shrimp *(Penaeus* spp.) in the northwestern Gulf of Mexico, 1961. U.S. Fish Wildl. Serv., Fish. Bull., 66(2):323-334.

MFR Reprint 966. From Marine Fisheries Review, *Vol. 35, Nos. 3-4. Copies of this reprint, in limited numbers, are available from D83, Technical Information Division, Environmental Science Information Center, NOAA, Washington, DC 20235.*

MFR REPRINT 967

A mathematical model capable of explaining and predicting changes in shrimp catch is one of the objectives of research at the Galveston Laboratory.

Gulf of Mexico Shrimp Resource Research

CHARLES W. CAILLOUET, JR., and KENNETH N. BAXTER

ABSTRACT

This paper describes shrimp resource research presently being conducted by the Galveston Laboratory of the National Marine Fisheries Service Gulf Coastal Fisheries Center. Discussed are plans for development of a mathematical model capable of explaining and predicting changes in shrimp catch, and on-going mark-recapture experiments, prediction of catch, stock identification studies, and study of spawning grounds. Trends in Texas and Louisiana brown and white shrimp catches and catch rates are presented.

INTRODUCTION

Shrimp resources of the Gulf of Mexico are the most valuable fishery resources of the United States. In 1972, Gulf coastal waters of the U.S. yielded 144 million pounds of shrimp (heads-off) with a dockside value of $165 million. The Gulf shrimp fisheries continue to expand, and improved management techniques will be required to assure perpetuation of the resources and to avoid overexploitation.

This paper describes shrimp resource research presently being conducted by the Galveston Laboratory of the NMFS Gulf Coastal Fisheries Center. The main objective of this research is to develop a mathematical model capable of explaining and predicting changes in shrimp catch. A systems analysis approach (Watt, 1966, 1968; Patten, 1971) is being used to develop the model. Such a model would be of considerable use in guiding management decisions. Though the research is concerned with brown shrimp *(Penaeus aztecus),* white shrimp *(P. setiferus),* pink shrimp *(P. duorarum),* and other commercial Penaeidae in the Gulf of Mexico, it is concentrated initially on brown and white shrimp in Texas and Louisiana.

LIFE CYCLE, ENVIRONMENT, AND FISHERIES

The shrimp life cycle and its interactions with environmental variation and shrimp fisheries represent a continuous and highly dynamic system that varies in time and space. For the most part shrimp resources are renewable annually. Shrimp are short-lived animals with a life cycle consisting of oceanic and estuarine phases (Figure 1). Marked fluctuations in the size of shrimp populations can probably be induced by yearly differences in spawning success and survival of young which depend to a large extent on biological and physical environmental conditions.

In addition to being vulnerable to natural mortality at all stages of their life cycle, shrimp begin to enter the catch as juveniles, and they are heavily exploited thereafter by inshore and offshore fisheries which are major competitors for shares of each shrimp crop (Figure 2). The degree to which catch from a given shrimp crop is influenced by allocation between these and other users (domestic sport fishermen and foreign vessels) is unknown. Furthermore, a varying proportion of the catch of small shrimp by the offshore fishery is wasted by being discarded at sea or in port for legal, economic, and other reasons.

RESEARCH IN PROGRESS

Gulf Coast Shrimp Data

As an initial step toward development of the model, we have begun preparation of the Gulf Coast Shrimp Data (from Division of Statistics, NMFS) for computer processing. Published monthly summaries of catch (by species, size class, area, and depth) and fishing effort (trips and days, by area and depth) for the years 1956-1972, are being transferred to punched cards. Kutkuhn (1962) has described many of the limitations of these data.

Mark-Recapture Experiments

A mark-recapture method using short-term sequential sampling is being tested to estimate population size, fishing mortality, other losses (natural mortality, emigration, marking mortality), and immigration of shrimp in tidal marsh ponds. It is anticipated that this or similar methods eventually will be tested in large areas where commercial and recreational shrimp trawling occurs. Such methods depend upon a decrease in the population of marked and unmarked animals caused by fishing during the course of the experiment.

Charles W. Caillouet, Jr., joined the staff of the NMFS Gulf Coastal Fisheries Center, Galveston Laboratory, in 1972. Kenneth N. Baxter, also a member of the Galveston staff, has conducted research on various life history stages of shrimp for 15 years. This paper is Contribution No. 365 from the NMFS Gulf Coastal Fisheries Center, Galveston Laboratory, Galveston, Tex. 77550.

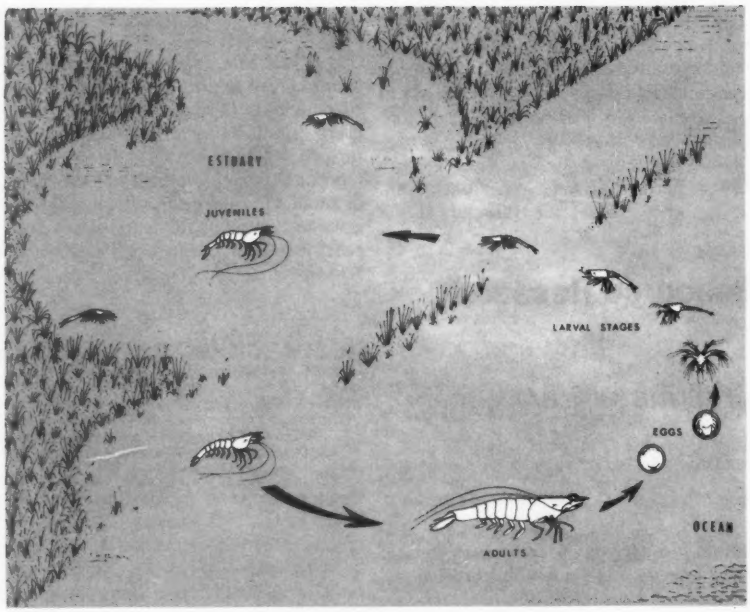


Figure 1 —Life cycle of shrimp (*Penaeus* spp.).

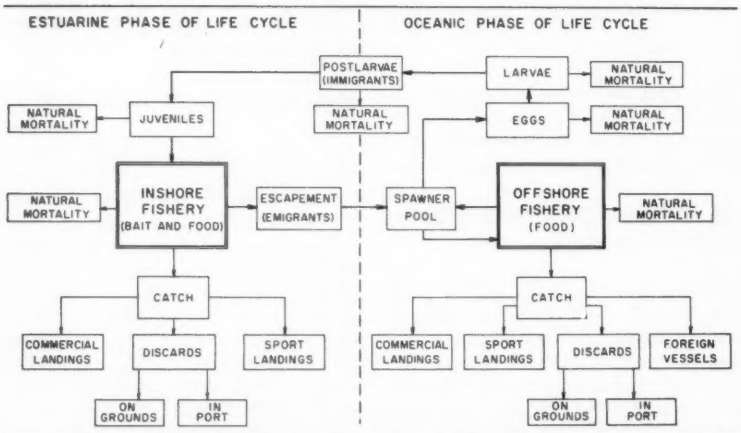


Figure 2.—Relationships among components of the life cycle of shrimp (*Penaeus* spp.) and components of the inshore and offshore shrimp fisheries.

Prediction of Catch

Indices of abundance of postlarval and juvenile shrimp have been used for more than a decade as predictors of shrimp catch (Berry and Baxter, 1969). Sampling of postlarval and juvenile shrimp in Galveston Bay is continuing for this purpose. The juvenile index (catch of brown bait shrimp/hour) for Galveston Bay has been an especially good predictor of offshore catch of brown shrimp in Texas waters (Table 1, Equation 1). Offshore and inshore annual catches are also correlated.

Based on annual summaries of Gulf Coast Shrimp Data, offshore catches have increased as inshore catches increased for both brown and white shrimp in Texas and Louisiana (Table 1). In other words, good shrimping years usually produced high catches offshore and inshore, and poor shrimping years usually produced low catches in both areas. The low correlation (Table 1, Equation 2) obtained for the relationship between offshore and inshore brown shrimp catch in Texas is probably due in part to legal limitations on inshore shrimping in Texas.

Spawning Grounds

An attempt is being made to determine if abundance of adult shrimp in certain areas offshore is related to chemical characteristics of recent bottom sediments. Grady (1971) has shown that shrimp abundance is greater in areas where sediments contain high concentrations of organic carbon. It is known that the ovaries of female shrimp do not ripen until the animals leave the estuaries, and this ripening seems largely a matter of deposition of yolk in the eggs (Caillouet, 1973; Lee and Lee, 1970). It is likely that female shrimp obtain lipids required for yolk synthesis from a diet of materials from these sediments. The sediments also might contain materials (hormone analogs) that stimulate ripening of ovaries. Among the food items that would be expected to occur in recent sediments would be phytoplankton. Diatoms have been shown to contain lipids which are assimilated rapidly by shrimp (Condrey, Gosselink, and Bennett, 1972).

Research plans include identification of lipids in shrimp ovaries and in the recent sediments on the offshore spawning grounds. Ovarian lipids of pink shrimp have already been identified (William Gehring, University of Miami, Florida, personal communication), and our analyses are being conducted on brown and white shrimp. Stage of ovarian development in samples of brown and white shrimp is also being determined.

Stock Identification

To determine whether or not separate stocks of a species can be identified by zone electrophoresis of protein extracts, various tissues from brown

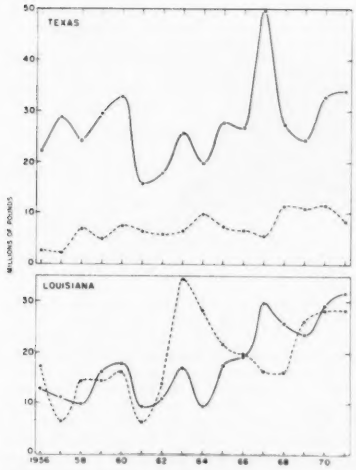


Figure 3.—Changes in annual catch (millions of pounds, heads-off) of brown shrimp (solid line) and white shrimp (dashed line) in Texas and Louisiana (Mississippi River to Texas).

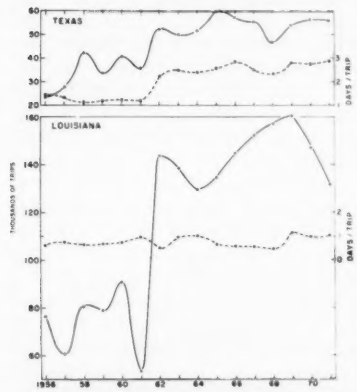


Figure 4.—Changes in annual fishing effort (thousands of trips, solid line) and annual number of days per trip (dashed line) in Texas and Louisiana (Mississippi River to Texas). (Note: Thousands of trips x days per trip = thousands of days, to estimate annual fishing effort in terms of days of fishing.)

Table 1.—Least squares regression relationships between offshore and inshore catches of brown and white shrimp in Texas and Louisiana (Mississippi River to Texas)[1]

Equation No.		Definition and Range of Variables Y and X	Least Squares Regression Equation and Correlation Coefficient, r
1	Y	Annual Offshore Catch (pounds, heads-off) of brown shrimp in Texas (range: 15,345,700-48,526,900)	$\hat{Y}=9{,}959{,}700+356{,}200X$ $r=0.85$
	X	Average Weekly Catch (pounds, heads-on) per hour of brown (bait) shrimp in Galveston Bay, Texas (based upon the period April 25-June 12 each year) (range:18-91)	
2	Y	Annual Offshore Catch (pounds, heads-off) of brown shrimp in Texas (range: 15,345,700-48,526,900)	$\hat{Y}=23{,}593{,}700+3.6231X$ $r=0.28$
	X	Annual Inshore Catch (pounds, heads-off) of brown shrimp in Texas (range: 9,700-1,853,500)	
3	Y	Annual Offshore Catch (pounds, heads-off) of brown shrimp in Louisiana (range: 2,129,900-17,659,500)	$\hat{Y}=2{,}767{,}500+0.8136X$ $r=0.73$
	X	Annual Inshore Catch (pounds, heads-off) of brown shrimp in Louisiana (range: 2,793,600-16,073,900)	
4	Y	Annual Offshore Catch (pounds, heads-off) of white shrimp in Texas (range: 405,600-6,479,800)	$\hat{Y}=1{,}636{,}500+0.6576X$ $r=0.58$
	X	Annual Inshore Catch (pounds, heads-off) of white shrimp in Texas (range: 782,200-6,072,300)	
5	Y	Annual Offshore Catch (pounds, heads-off) of white shrimp in Louisiana (range: 3,823,800-20,601,900)	$\hat{Y}=3{,}446{,}300+1.4105X$ $r=0.86$
	X	Annual Inshore Catch (pounds, heads-off) of white shrimp in Louisiana (range: 1,748,500-13,793,600)	

[1] Equation 1 is based upon data from 1960 to 1972, and all other equations are based upon data from 1956 to 1971.

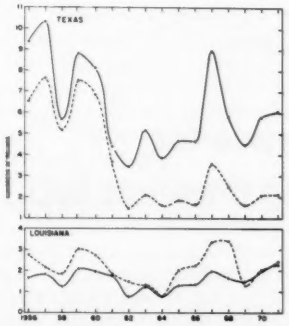


Figure 5.—Changes in annual catch per day (dashed line) and annual catch per trip (solid line) for brown shrimp in Texas and Louisiana (Mississippi River to Texas). Catch rates are expressed in hundreds of pounds, heads-off.

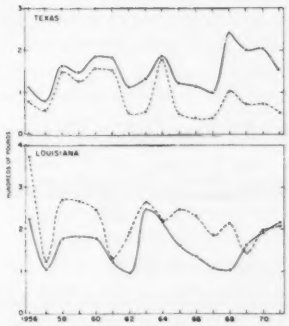


Figure 6.—Changes in annual catch per day (dashed line) and annual catch per trip (solid line) for white shrimp in Texas and Louisiana (Mississippi River to Texas). Catch rates are expressed in hundreds of pounds, heads-off.

and white shrimp are being tested. Trace metal composition of shrimp tissues is being determined also, because it might provide a means for identifying the estuarine origin of particular offshore shrimp populations.

Texas and Louisiana Trends

Based upon annual summaries of Gulf Coast Shrimp Data, there have been apparent trends of increase in total catch (Figure 3) of brown and white shrimp and in fishing effort (Figure 4) in both Texas and Louisiana. The average duration of a shrimping trip in Louisiana was near 1 day, and this reflected the preponderance of inshore fishing in that state. The increase in average duration of a shrimping trip in Texas reflected the increase in offshore fishing (Figure 4).

Apart from observed fluctuations in catch per trip for brown and white shrimp in Texas and Louisiana there seems to have been no pronounced trend (Figures 5 and 6), and the same is suggested for catch per day for white shrimp in Texas and Louisiana and for brown shrimp in Louisiana. However, there has been an apparent decrease in catch per day for brown shrimp in Texas (Figure 5). These apparent trends do not take into account the known increases in size and efficiency of shrimp trawlers over the years covered by these data, nor have they been corrected for

possible trends of improvement in the collection and analysis of catch and effort data. An in-depth analysis of the Gulf Coast Shrimp Data is planned to resolve some of these problems.

State-Federal Coordination of Research

Certain aspects of the research are being coordinated with similar research conducted by the Texas Parks and Wildlife Department and the Louisiana Wild Life and Fisheries Commission. Gulf Coastal Fisheries Center biologists are participating in shrimp research cruises of the Texas Parks and Wildlife Department's research vessel *Western Gulf*, and they are working closely with biologists of the Louisiana Wild Life and Fisheries Commission in conducting mark-recapture experiments in estuarine areas.

REFERENCES

Berry, R. J. and K. N. Baxter. 1969. Predicting brown shrimp abundance in the northwestern Gulf of Mexico. FAO (Food Agr. Organ. U.N.) Fish. Rep. 3(57):775-798.

Caillouet, C. W., Jr. 1973. Ovarian maturation induced by eyestalk ablation in pink shrimp, *Penaeus duorarum* Burkenroad. *In* Proc. 3rd Annual Meeting and Workshop, World Mariculture Society, Division of Continuing Education, Louisiana State University, Baton Rouge, La. (In press.)

Condrey, R. E., J. G. Gosselink and H. J. Bennett, 1972. Comparison of the assimilation of different diets by *Penaeus setiferus* and *P. aztecus*. Fish. Bull. U.S. 70:1281-1292.

Grady, J. R. 1971. The distribution of sediment properties and shrimp catch on two shrimping grounds on the continental shelf of the Gulf of Mexico. Proc. Gulf Caribb. Fish. Inst. 23:139-148.

Kutkuhn, J. H. 1962. Gulf of Mexico commercial shrimp populations—trends in characteristics, 1956-59. U.S. Fish Wildl. Serv. Fish. Bull. 62(212):343-402.

Lee, T. Y. and B. D. Lee. 1970. Ovarian cycle and oogenesis in *Penaeus japonicus* Bate. Pusan Fish. College Mar. Lab. Publ. 3:45-52.

Patten, B.C. (editor) 1971. Systems analysis and simulation in ecology. Acad. Press, N.Y., 607 p.

Watt, K. E. F. (editor) 1966. Systems analysis in ecology. Acad. Press, N.Y., 276 p.

Watt, K. E. F. 1968. Ecology and resource management. McGraw-Hill Book Co., N.Y. 450 p.

MFR Reprint 967. From Marine Fisheries Review, *Vol. 35, Nos. 3-4. Copies of this reprint, in limited numbers, are available from D83, Technical Information Division, Environmental Science Information Center, NOAA, Washington, DC 20235.*

MFR REPRINT 968

A new device permits the sampling of postlarval shrimp in the passes in which the main volume of tidal flow occurs.

An Automatic Pumping Device for Sampling Postlarval Shrimp (*Penaeus* spp.)

FRANK MARULLO

ABSTRACT

Described is an automatic sampling device used to collect and preserve postlarval shrimp (Penaeus *spp.). At timed intervals, seawater is pumped through collecting nets which retain samples of organisms including shrimp. A maximum of 12 samples can be collected in 24 hours. Each sample is preserved immediately in 10 percent Formalin. These samples may be removed once after each 24 hours of operation, or they may be accumulated with similar samples over a longer period of time. Comparison is made between catches with the automatic device and those made with the Renfro beam trawl.*

INTRODUCTION

In the early 1960's, studies were initiated to investigate the possibility of predicting brown shrimp (*Penaeus aztecus* Ives) commercial landings from indices of abundance of postlarval shrimp collected during their movement into Gulf coastal bays (Baxter, 1963). A similar approach has been used in the same region by other investigators (St. Amant, Corkum, and Broom, 1963; Christmas, Gunter, and Musgrave, 1966; St. Amant, Broom, and Ford, 1966; Baxter and Renfro, 1967; Berry and Baxter, 1969). The samples of postlarvae collected in these investigations were taken with a 1.5-m, hand-drawn beam trawl described by Renfro (1962). Though this device samples postlarval shrimp effectively, it is subject to the limitations that (1) sorting of the samples is time-consuming owing to collection of detritus by the trawl, and (2) sampling must be conducted in shallow water away from the passes in which the main volume of tidal flow occurs. In addition, the sampling operation is often time-consuming and difficult.

The present paper describes an automatic sampling device that was designed to alleviate these problems. This sampler has been tested near Galveston Bay, Texas, for extended periods and has proven to be satisfactory for the collection of small, detritus-free samples from the main tidal flow at frequent intervals.

DESCRIPTION OF GEAR

The automatic sampler consists of a pump, a diesel engine, an electronic control panel, and a turntable equipped with a series of nets for collecting, preserving, and storing samples. Numbers

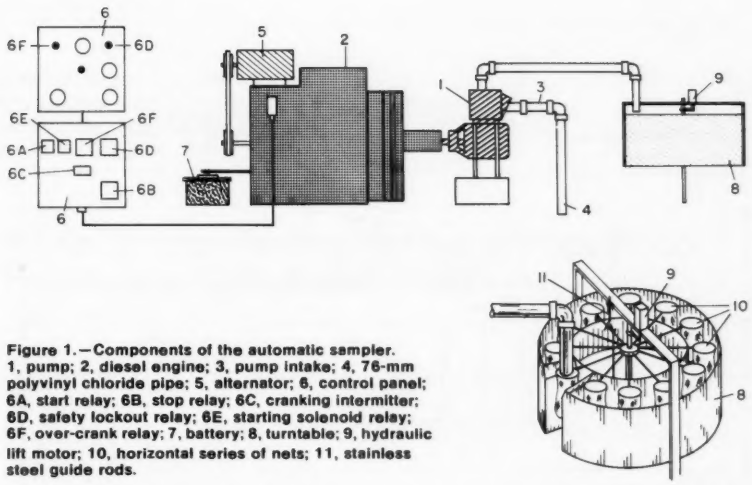


Figure 1.—Components of the automatic sampler. 1, pump; 2, diesel engine; 3, pump intake; 4, 76-mm polyvinyl chloride pipe; 5, alternator; 6, control panel; 6A, start relay; 6B, stop relay; 6C, cranking intermitter; 6D, safety lockout relay; 6E, starting solenoid relay; 6F, over-crank relay; 7, battery; 8, turntable; 9, hydraulic lift motor; 10, horizontal series of nets; 11, stainless steel guide rods.

in parentheses in the text that follows correspond to those used for identification of the components of the sampler in Figure 1.

A Gorman Rupp[1] self-priming, centrifugal type pump (Model 12B2B) equipped with a two-vane ductile iron impeller was used (1). The impeller is designed to handle solids up to 51 mm in diameter without damage; the back of the impeller shroud has pump-out vanes to prevent binding. The pump intake (3) has a 51-mm opening. A flexible rubber hose (0.6 m long) joined to a 76-mm polyvinyl chloride pipe (4) was attached to the intake. A removable end plate provides easy access to the pump interior for quick inspection and maintenance.

A 5¼hp Lister diesel engine (2) was used to drive the pump. This engine provided ample power for both the pump and alternator (5). A light-weight diesel fuel, essential for operation in winter, was used to assure fast starting.

The control panel (6), which was custom-made by Frank W. Murphy Manufacturer, Inc., Houston, Texas, was powered by a heavy-duty, 12-volt, 225 ampere-hour battery (7). The battery was kept fully charged by a 12-volt 85-amp alternator (5) equipped with a voltage regulator (not shown) attached to the diesel engine. The control panel was equipped with start and stop relays (6A and 6B, respectively) set to time the cycle of operation. These provided delayed switch transfer on energization of the coil and delayed resetting upon coil deenergization. Each delay was independently adjustable. When the start relay (6A) was in the "on" position, it energized the cranking intermitter (6C), which in turn sent current to the starting solenoid relay (6E), the safety lockout relay (6D), and to the starter (not shown) which started the pump. When the pumping cycle was completed, the stop relay (6B) deenergized the panel and stopped the pump.

The control panel was equipped with two safety devices. One was designed to protect the battery by controlling the number of times the starter would be engaged. This device repeated the starting cycle three times. If the engine did not start after the third try, the overcrank relay (6F) tripped a reset button which stopped all current. The other safety device, the safety lockout relay (6D) was a low oil pressure switch. If the engine's oil pressure dropped below normal during operation, the switch activated a reset button which stopped all current. Once the safety switch shut off the system, manual starting was required.

Frank Marullo is a Biological Technician, NMFS Gulf Coastal Fisheries Center, Galveston Laboratory, Galveston, Tex. This is Contribution No. 360, NMFS Gulf Coastal Fisheries Center, Galveston Laboratory, Galveston, Tex. 77550.

[1] The use of trade names in this publication does not imply endorsement of commercial products.

The turntable (8) for collecting, preserving and storing specimens consisted of a 0.9-m diameter fiberglass tank containing 10 percent Formalin, a hydraulic lift motor (9), and a horizontal series of nets (10). A 152-mm section was cut away from the tank to allow the sampled water to pass through a net and be discarded. Twelve 102-mm rings mounted over the tank were fitted with nets having 1-mm² bar mesh. After each pumping cycle, the turntable rotated, deposited the net containing the fresh sample of the Formalin bath, and positioned the next net over the cutaway to receive the next sample. Turning and positioning of the nets were controlled by a stainless steel guide rod bent at a 45-degree angle over the support rods (11) and by a Y-shaped rod mounted below. As the hydraulic motor lifted the nets, the rods guided them into position.

METHODS

The automatic sampler was tested in the Bolivar Roads Tidal Pass, the major entrance to Galveston Bay, Texas, during 1968-1970. The intake pipe was positioned 1 m below the surface in 4.6 m of water. The device occasionally malfunctioned during initial testing. Most malfunctions were traced to the control panel, but water in the fuel and breakdown of the holding tank and turntable were other causes of malfunction. Before testing was terminated, however, the sampler operated without failure for 120 consecutive days.

RESULTS AND DISCUSSION

To assess the effectiveness of the automatic sampler in capturing postlarval shrimp, a comparison (Figure 2) was made of catches taken with the sampler and with the Renfro beam trawl (unpublished data, K. N. Baxter) at opposite sides of the Bolivar Roads ship channel. The maximum average catch of postlarvae per hour with the automatic sampler was near 5. Catch per tow with the beam trawl was greater than catch per hour with the automatic sampler, and catches with the two types of gear appeared unrelated.

The automatic sampler was operated during all tide stages and over a several-day period in many cases (Figure 2). Since catches collected by the de-

vice were small, this tended to mask fluctuations in abundance of postlarvae that were measured with the beam trawl. In an earlier study (Baxter, 1965) plankton samples taken at Rollover Pass, Gilchrist, Texas, contained greater numbers of postlarvae during flood tides than during other tide stages. It is believed that catches could be increased by enlarging the intake to the pump and by facing it seaward in the channel. A similar device with a larger intake already has been used successfully by Fontaine et al. (1972). A switch activated by incoming tidal currents also could be added to the sampler to allow its operation only during flood tides.

The automatic sampler could be used to measure diel fluctuations in catch (related to tide stage, time of day, etc.), if the catches in each of the 12 sample bags were removed and examined separately after each 24 hours of operation.

LITERATURE CITED

Baxter, K.N. 1963. Abundance of postlarval shrimp—one index of future shrimping success. Proc. Gulf Caribb. Fish Inst. 15:79-87.

_____. 1966. Abundance of postlarval and juvenile shrimp. *In* Annual report of the Bureau of Commercial Fisheries Biological Laboratory, Galveston, Texas for fiscal year 1965. U.S. Fish Wildl. Serv., Circ. 246, p. 26-27.

_____, and W. C. Renfro. 1967. Seasonal occurrence and size distribution of postlarval brown and white shrimp near Galveston, Texas, with notes on species identification. U.S. Fish Wildl. Serv., Fish. Bull. 66:149-158.

Berry, R.J., and K. N. Baxter. 1969. Predicting brown shrimp abundance in the northwestern Gulf of Mexico. FAO Fish. Rep. 57(3):775-798.

Christmas, J. Y., G. Gunter, and P. Musgrave. 1966. Studies of annual abundance of postlarval penaeid shrimp in the estuarine waters of Mississippi, as related to subsequent commercial catches. Gulf Res. Rep. 2:177-212.

Fontaine, C. T., S. E. P. Gislason, and W. L. Trent. 1972. A system for collecting large numbers of live postlarval penaeid shrimp. Fish. Bull., U.S. 70:1298-1302.

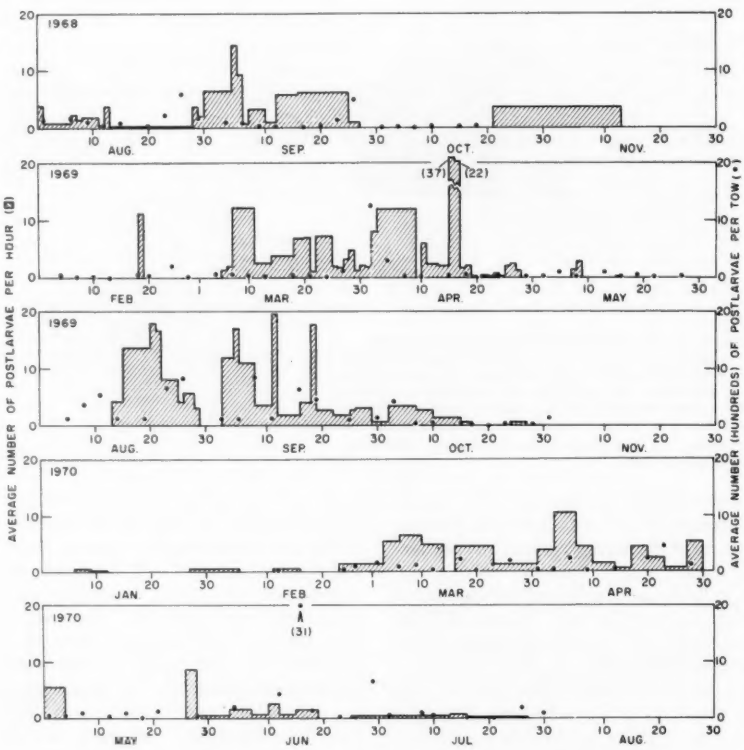


Figure 2.—Catches of postlarvae with the automatic sampler (average number per hour)—shaded—and with the Renfro beam trawl (average number per tow)—black dots.

Renfro, W. C. 1963. Small beam net for sampling postlarval shrimp. *In* Biological Laboratory, Galveston, Tex. Fishery Research for the year ending June 30, 1962. U.S. Fish. Wildl. Serv., Circ. 161, p. 86-87.

St. Amant, L. S., J. G. Broom, and T. B. Ford. 1966. Studies of the brown shrimp, *Penaeus aztecus*, in Barataria Bay, Louisiana, 1962-1965. Proc. Gulf Caribb. Fish. Inst. 18:1-17.

St. Amant, L. S., K. C. Corkum, and J. G. Broom. 1963. Studies on growth dynamics of the brown shrimp, *Penaeus aztecus*, in Louisiana waters. Proc. Gulf Caribb. Fish. Inst. 15:14-26.

MFR Reprint 968. From Marine Fisheries Review, *Vol. 35, Nos. 3-4. Copies of this reprint, in limited numbers, are available from D83, Technical Information Division, Environmental Science Information Center, NOAA, Washington, DC 20235.*

MFR REPRINT 969

A 4.5-acre pond serves as a test site for the effects of fishing, emigration, and natural mortality on white shrimp.

White Shrimp *(Penaeus setiferus)* Population Trends in a Tidal Marsh Pond

STEPHEN H. CLARK and CHARLES W. CAILLOUET, JR.

ABSTRACT

Ketchen's modification of the Leslie fishing success method was used to estimate initial population and rates of immigration, fishing, and other losses (emigration and natural mortality) in a white shrimp (Penaeus setiferus) *population in a Texas tidal marsh pond. The significant decline in catch rates of marked and unmarked shrimp during the experiment was due to fishing and other causes (emigration and natural mortality), but the reduction due to fishing was less than that due to other causes. We believe that this or similar methods offer considerable promise in future studies of this nature.*

INTRODUCTION

The growing need for more intensive management of the shrimp resources of the Gulf of Mexico has stimulated renewed interest in the study of penaeid shrimp population dynamics. Comparison of the rates of fishing and natural mortality is of particular interest, since such information is essential to determining the relative influence of inshore (estuarine) and offshore fishing on total yield. Information on population size and rates of migration is also needed. Since changes in shrimp populations take place very rapidly, we are using "fishing success" methods based on short-term sequential sampling or fishing in conjunction with concurrent mark-recapture experiments to obtain estimates of population and rates of fishing, natural mortality, and migration. We are conducting our initial tests of this technique in estuarine areas in which we control the intensity of fishing (sampling). If successful, we plan to expand the use of the technique to areas in which commercial and sport shrimping occur.

According to Ricker (1958), fishing success methods are applicable when fishing is of sufficient intensity to reduce significantly the catch per unit of effort (C_t/f_t, in which t is an interval of time). This concept appears to have originated with Leslie and Davis (1939), who related the decline in catch per unit effort to cumulative catch. Later DeLury (1951) related the decline in the logarithm of catch per unit effort ($\ln | C_t/f_t |$) to cumulative effort (E_t). DeLury also recognized that concurrent mark-recapture experimentation could provide valuable additional information on changes in catchability and on trends in population. Ketchen (1953) later applied this principle to estimate initial population, emigration, and immigration in a population of lemon soles (*Parophrys vetulus*), in which it was assumed that there was no significant excess of recruitment over natural mortality (or the reverse).

Our study applied Ketchen's (1953) modification of the Leslie method to estimate initial population and trends in a population of white shrimp (*Penaeus setiferus*) in a tidal marsh pond. Although intensity of fishing was controlled in our experiment, we believe that this method, or similar ones, holds considerable promise for use in areas where commercial and sport fishing occur.

Both Stephen H. Clark and Charles W. Caillouet, Jr. are members of the staff of the NMFS Gulf Coastal Fisheries Center, Galveston Laboratory. This paper is Contribution No. 366 from the NMFS Gulf Coastal Fisheries Center, Galveston Laboratory, Galveston, Tex. 77550.

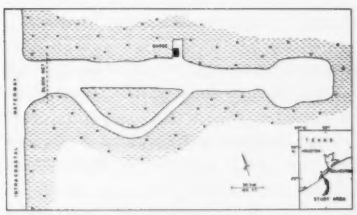


Figure 1.—Map of study area.

STUDY AREA AND METHODS

The study was conducted during 6-9 November 1972, in an unnamed tidal marsh pond in Brazoria County, Texas. This pond, 4.5 acres in size, is located 3 miles northeast of Freeport and is connected to the Intracoastal Waterway (Figure 1). Average depth at MLW is approximately 4 feet. This pond was selected because it has a well-defined shoreline that seldom floods at high tide, a trawlable bottom, and a narrow entrance that can be blocked with netting.

To prevent immigration and emigration of shrimp we blocked the entrance (Figure 1) on October 6 with netting (½-inch stretch mesh). This was left in place until the study terminated. Shrimp were collected the following day with a 10-foot flat otter trawl (½-inch stretch mesh) towed with a 16-foot skiff powered by an 18 hp outboard motor. A sample of shrimp was measured (total length, tip of rostrum to tip of telson),

and those remaining were held in aerated containers until 2,054 were marked by injection with 2% neon red fluorescent pigment as described by Klima (1965). To minimize marking mortality, we attempted to mark only shrimp 40 mm in total length or larger. Marked shrimp were retained in a holding pen (within the pond) of nylon netting (¼ -inch stretch mesh) until marking was completed. Of the shrimp marked, 2,004 were liberated randomly throughout the pond. The remaining 50 were kept in the holding pen for the duration of the study to measure marking mortality; 50 unmarked shrimp also were held in the pen as a control.

On both 8 and 9 November, between 0815 and 1330, 23 sequential 5-minute tows were made with the otter trawl. The 46 samples were examined under ultraviolet light to identify marked individuals, and the numbers of marked and unmarked shrimp captured in each tow were recorded. Total length of all marked shrimp and up to 50 unmarked shrimp from each tow was measured. Length-frequency distributions of these and the initial sample of shrimp collected prior to marking are shown in Figure 2. All shrimp caught (regardless of size) were used in our analyses.

RESULTS AND DISCUSSION

We estimated initial population ($\hat{N}$, Table 1) using Bailey's (1951) modification of the Petersen formula

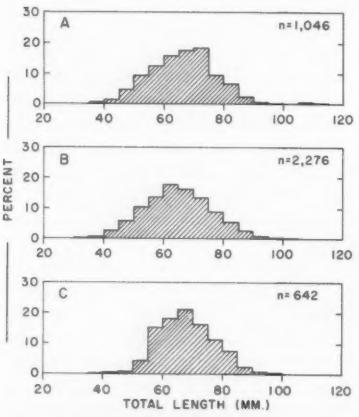


Figure 2.—Length-frequency distributions (in percent) of white shrimp: (A) Shrimp collected prior to marking; (B) unmarked shrimp caught during the study; and (C) marked shrimp caught during the study.

$$\hat{N} = \frac{M(C+1)}{R+1}$$

in which

M=Number of marked shrimp released

C=Number of shrimp caught or sample taken for census

R=Number of recaptured marked shrimp in the sample.

The 95% confidence limits for the true population, N, were estimated from the large sample variance formula of Bailey (1951).

We calculated the least squares regression of catch on cumulative catch for both unmarked and marked shrimp (Figures 3 and 4) by

$$C_t = cN_a - cK_t$$

and

$$R_t = c'M_a - c'J_t$$

in which

C_t = Number of unmarked shrimp caught in tow t

R_t = Number of marked shrimp caught in tow t

c = Catchability of unmarked shrimp

c' = Catchability of marked shrimp

N_a = Apparent initial population of unmarked shrimp

M_a = Apparent initial population of marked shrimp

K_t = Cumulative number of unmarked shrimp caught, to the start of tow t

J_t = Cumulative number of marked shrimp caught, to the start of tow t.

We used catch rather than catch per unit effort because effort was constant. In this case, t can refer to tow or time interval because duration of each tow was held constant. Estimates of apparent initial population, initial population, and instantaneous rates of fishing, "other losses", and immigration were obtained by the methods of Leslie and Davis (1939) and Ketchen (1953) as described by Ricker (1958).

The instantaneous rate of fishing, p, was estimated by

$$p = \frac{M_a\,(c'f)}{M}$$

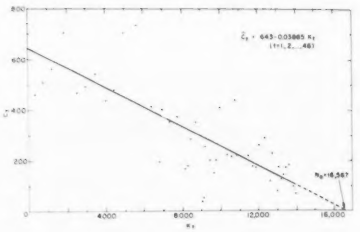


Figure 3.—Leslie plot of catches of unmarked white shrimp. Ordinate is catch in tow t (C_t), and abscissa is cumulative catch to start of tow t (K_t).

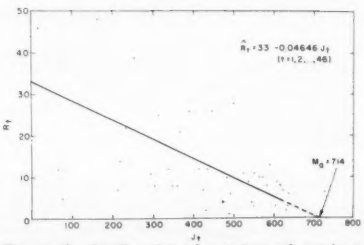


Figure 4.—Leslie plot of catches of marked white shrimp. Ordinate is recaptures in tow t (R_t) and abscissa is cumulative catch to start of tow t (J_t).

in which

f=Total number of tows.

The instantaneous rate of "other losses", y, was estimated by

$$y = c'f - p.$$

Other losses could include emigration, natural mortality, and marking mortality. None of the 50 marked shrimp held in the pen died during the experiment,

Table 1.—Estimates of initial population[1], number caught, number of immigrants and number of other losses of white shrimp in a tidal marsh pond.

Type of estimate	Calculated values
Modified Petersen	
Initial population, $\hat{N}$	45,535(42,029-49,041)
Leslie	
Apparent initial population, N_a	16,567(15,139-18,685)
Ketchen	
Initial population, $\hat{N}$	38,899
Number caught, C	13,989
Number of immigrants, $\hat{I}$	6,434
Number of other losses, $\hat{O}$	25,294

[1]95% confidence limits are given in parentheses.

but one of the 50 unmarked shrimp held as a control died. It was assumed, therefore, that marking mortality was negligible, and that "other losses" included only emigration and natural mortality. The instantaneous rate of immigration, z, was estimated by

$$z = c'f - cf.$$

The apparent initial population, (N_a, Table 1) was estimated by the Leslie method (Figure 3), and an estimate of the initial population ($\hat{N}$, Table 1), was obtained by

$$\hat{N} = N_a\ (p + y - z)\ /p.$$

The average population, N, was estimated from

$$\overline{N} = C_u/p$$

in which

C_u = Total number of unmarked shrimp caught.

An estimate of the number of immigrants ($\hat{I}$, Table 1), was obtained by

$$\hat{I} = z\overline{N}$$

and the estimated number of "other losses" ($\hat{O}$, Table 1) was obtained by

$$\hat{O} = y\overline{N}.$$

It is obvious that the total number of unmarked animals caught is

$$C_u = p\overline{N}.$$

As developed above, this method gives $\hat{N}$ for unmarked animals only. In situations in which large populations are sampled, the discrepancy caused by exclusion of marked animals from the estimate is slight, but for smaller populations adjustments may be desirable to account for marked animals. Such adjustments could be made by (1) adding the total number of marked animals to the Ketchen estimate of $\hat{N}$, and by (2) calculating $\overline{N}$ from

$$\overline{N} = (C_u + C_m)/p$$

in which

C_m = total number of marked animals caught.

The large discrepancy between the Petersen and Leslie estimates ($\hat{N}$ and N_a, Table 1) would be corrected partially by such adjustments. We believe that the difference observed also can be attributed in part to (1) inflation of the Petersen estimate by immigration, and (2) depression of the Leslie estimate by "other losses" (emigration and natural mortality).

Though the area was blocked during the study, the net was ripped and may have been lifted off the bottom on several occasions by tidal currents and by the wakes of tugs pushing barges on the Intracoastal Waterway. Though the net was quickly repaired, there was still ample opportunity for emigration and immigration to occur. Natural mortality during the experiment in unknown, but it is probable that such losses were of lesser consequence because the study was of short duration. Losses due to fishing were exceeded by "other losses" (emigration and natural mortality). Marking mortality was assumed to be negligible in that no mortalities occurred in marked shrimp held in the pen during the study (see section on Study Area and Methods). Consequently, we believe that emigration was chiefly responsible for the decline in catch during the study.

Two additional sources for error remain to be considered. First, heterogeneity of variance was apparent in the data for marked animals (Figure 4). This may have biased our least squares regression estimates for marked shrimp and other estimates derived therefrom. Shrimp catch data usually exhibit greater variability at higher levels of abundance than at lower levels. However, the catch data for unmarked shrimp (Figure 3) do not appear to be heterogeneous. Another possible source of error would be differences in length-frequency between marked and unmarked populations of shrimp. There was a slight difference between the length distributions (Figure 2) of marked and unmarked shrimp in the study, but it was considered to be of little consequence.

In future studies, greater care will be taken in preventing shrimp migrations. Areas less subject to tidal extremes and wakes of boats will be chosen for study. In such cases, the "other losses" should represent natural mortality, provided that losses due to marking are negligible.

LITERATURE CITED

Bailey, N.J.J. 1951. On estimating the size of mobile populations from recapture data. Biometrika, 38:293-306.

DeLury, D. B. 1951. On the planning of experiments for the estimation of fish populations. J. Fish. Res. Bd. Canada, 8:281-307.

Ketchen, K. S. 1953. The use of catch-effort and tagging data in estimating a flatfish population. J. Fish. Res. Bd. Canada, 10:459-485.

Klima, E. F. 1965. Evaluation of biological stains, ink, and fluorescent pigments as marks for shrimp. U.S. Fish. Wildl. Serv., Spec. Sci. Rept. Fish. No. 511, 8 pp.

Leslie, P. H., and D. H. S. Davis. 1939. An attempt to determine the absolute number of rats on a given area. J. Animal Ecol., 8:94-113.

Ricker, W. E. 1958. Handbook of computations for biological statistics of fish populations. Fish. Res. Bd. Canada Bull., 119:300 pp.

MFR Reprint 969. From Marine Fisheries Review, *Vol. 35, Nos. 3-4. Copies of this reprint, in limited numbers, are available from D83, Technical Information Division, Environmental Science Information Center, NOAA, Washington, DC 20235.*

The NMFS laboratory in Miami is engaged in studies of the shrimp fisheries off Mexico, in the Caribbean, and off South America.

Shrimp Research Program at Southeast Fisheries Center

Shrimp research at the Southeast Fisheries Center, Miami, concerns shrimp stocks off foreign coasts. The United States has important distant-water shrimp fisheries in the Gulf of Mexico off Mexico, in the Caribbean Sea, and off the northeast coast of South America (Figure 1). In 1970 landings by U.S. boats from these fisheries were approximately 30 million pounds (heads-off weight). The U.S. vessels operating in these waters are based either in foreign ports close to the fishing grounds or in U.S. domestic ports, depending on the distance of the fishing grounds from the continental United States. In the late 1940's and 1950's the U.S. shrimp industry and NMFS were instrumental in establishing and developing these fisheries that now are participated in by fishermen of a number of countries.

The Center's research program assembles and analyzes biological and statistical data on these fisheries, makes projections of their future prospects, and provides the information necessary to protect U.S. fishing rights and U.S. interests in conservation and management of the resources.

The Guianas shrimp fishery off the northeast coast of South America began in 1959. At present about 200 U.S. flag shrimp trawlers and also trawlers of Trinidad and Tobago, Guyana, Brazil, Japan, and Korea fish in coastal waters between Brazil and Guyana. These trawlers are modern in design and many of them are fitted with mechanical refrigeration for preservation of the catch and constructed of steel or fiberglass to reduce maintenance costs and prolong their life in tropical waters. In May 1972 the United States and Brazil signed an Agreement covering the operations of U.S. and Brazilian flag vessels in a specified area off Brazil during the period 1972-1973. As part of the Agreement, U.S. vessels keep logbook records of their catch and effort in the area. Figure 2 shows the record form that is used by U.S. vessels. On a voluntary basis, these vessels also record the same information for other parts of the fishing grounds. The Center's scientific staff processes and analyzes these data by computer techniques. The data have been submitted since July 1972 and form the nucleus of a shrimp fishery data bank which will provide information on the seasonal and areal variations in catch and effort, the structure of the stocks, and the expected yield from the fishery.

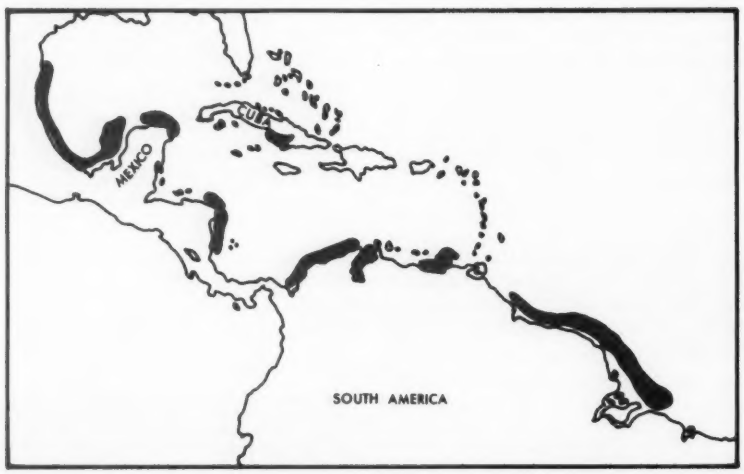


Figure 1.—Important shrimp fishing grounds in the Gulf of Mexico (south of the continental United States), in the Caribbean Sea, and off the northeastern coast of South America. Shrimp stocks on these grounds, some of which are fished by U.S. flag vessels, are under study at the Southeast Fisheries Center.

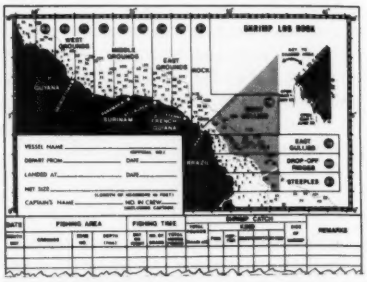


Figure 2.—Record form used by U.S. vessels.

The Center's research vessel *Oregon II* was assigned in June-July 1972 to collect information on the species composition of the shrimp in the Guianas fishery. Three species of grooved shrimp (the southern pink shrimp, the southern brown shrimp, and the spotted pink shrimp), make up the majority of the commercial catch, but the percentage composition of the catch by species and the differences in distribution between the three species were unknown. Data collected on the cruise showed that, in the area surveyed, the southern brown shrimp and the spotted pink shrimp were more abundant than the southern pink shrimp and, furthermore, that the distribution patterns of the three species were different. This information is expected to be useful in interpreting the logbook data submitted by the fishermen, since a necessary requisite of management is that the catch of each species be estimated separately.

The U.S. shrimp fishery in the Gulf of Mexico off the coast of Mexico began in 1945. The fishery reached a peak in the early 1950's, when about 25 million pounds were caught. Since that time, the U.S. fishery has declined (to 9 million pounds in 1970) because of economic and industry problems and an unexplained decline in the Campeche shrimp population in the middle 1960's. Fishing by Mexican and more recently by Cuban vessels has increased. The U.S. shrimp fishery off Mexico can be divided into: the brown shrimp fishery off the east coast of Mexico west of longitude 94°W, the pink shrimp fishery in the Campeche area, and the spotted pink shrimp and rock shrimp fishery in the Yucatan (Contoy) area. Work at the Center includes summarizing the extensive statistical data collected for the U.S. fishery since 1956 and using these data and other information about the stocks to determine the available yield and the best means to harvest the resource.

Since these distant-water shrimp fisheries are participated in by foreign as well as by U.S. fleets, international cooperation is essential to collect and analyze the total data for each fishery. The Center participates in the fisheries program of CICAR (Cooperative Investigations in the Caribbean and Adjacent Regions) which currently has under review the shrimp fisheries in this geographical area.

MFR REPRINT 970

Distribution of Commercial Shrimp off the Northeastern Coast of South America

ROBERT C. CUMMINS, JR., and ALBERT C. JONES

The shrimp fishing grounds off the coasts of Guyana, Surinam, and French Guiana were surveyed by the RV *Oregon II* of the Southeast Fisheries Center in June and July 1972 to determine the species distribution of shrimp available to the commercial fishery. The survey was conducted along 14 transect lines approximately 30 miles apart, from Georgetown, Guyana to Cabo Orange, Brazil. A total of 67 fishing stations was occupied along the transects, generally at 5-fathom intervals between 15 and 35 fathoms (Figure 1). At each station double-rigged, standard 40-foot, 4-seam flat trawls fabricated with 2-inch stretched mesh nylon netting and 1 ¾-inch mesh cod ends were used. Water temperatures and surface and bottom

Robert C. Cummins, Jr., and Albert C. Jones are with the NMFS Southeast Fisheries Center, Brunswick, Ga. and Miami, Fla.
This paper is Contribution No. 226, NMFS Southeast Fisheries Center, Miami, Fla. 33149.

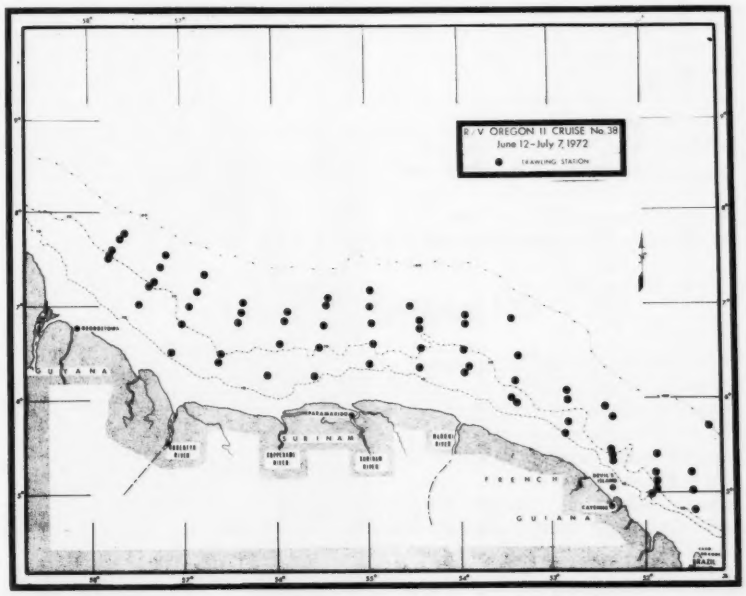


Figure 1.—Trawling stations occupied on RV *Oregon II* cruise 38. Positions, depths, and water temperatures at the stations and a summary of the catches are given in the fishing log (Table 1).

Table 1.—Fishing log, *Oregon II*, cruise 38.

Station Number	Date 1972	Position N. Lat.	Position W. Long.	Depth (fms)	Minutes Fished	Temperature Surf.	Temperature Bot.	SHRIMP CATCH Approx. wt (lbs)	SHRIMP CATCH Predominant Species (common names)	FISH CATCH Approx. wt (lbs)	FISH CATCH Predominant and/or Commercial Species (common names)
11996	6/21	7°34′	57°48′	15	30	81	78	1	Pink	34	Goatfish 11#, Sand Perch 6#, Seatrout 5#
11997	6/21	7°36′	57°47′	20	30	30	81	1	Pink	22	Flounder 4#, Seatrout 4#
11998	6/21	7°37′	57°47′	25	30	82	78	12	Pink	32	Seatrout 11#, Searobin 7#, Flounder 3#
11999	6/22	7°46′	57°43′	30	32	82	77	3	Pink spotted	45	Grunt 10#, Snapper 6#, Filefish 4#
12000	6/22	7°38′	57°38′	35	60	82	79	<1	Pink spotted	165	Vermillion Snapper 65#, Carib. Red Snapper 42#, Mutton Snapper 6#, Grunt 14#, Soldierfish 6#
12001	6/22	7°35′	57°12′	36	30	80	76	1	Pink spotted	23	Sand Perch, Flounder, Puffer
12002	6/22	7°26′	57°14′	30	30	80	77	2	Pink spotted	37	Filefish 10#, Bigeye 4#
12003	6/22	7°19′	57°19′	25	60	80	78	2	Pink spotted	81	Goatfish 30#, Flounder 12#, Filefish 7#
12004	6/23	7°16′	57°22′	20	26	81	78	3	Pink spotted	44	Seatrout 6#, Sand Perch 5#, Goatfish 4#
12005	6/23	7°03′	57°29′	15	30	82	82	2	Pink spotted	71	Pigfish 18#, Snapper 12#, Seatrout 6#
12006	6/23	6°32′	57°08′	15	30	80	80	19	Pink	220	Grunt 68#, Croaker 62#, Seatrout 35#, Mojarras 16#
12007	6/23	6°50′	57°01′	20	30	80	80	1	Pink spotted	48	Goatfish 17#, Sand Perch 15#
12008	6/24	7°02′	56°56′	25	30	80	77	<1	Pink spotted	50	Grunt 21#, Snakefish 6#
12009	6/24	7°11′	56°51′	30	30	80	77	<1	Pink spotted	85	Grunt 36#, Porgey 4#
12010	6/24	7°22′	56°46′	35	30	81	75	9	Pink spotted	53	Snapper 15#, Searobin 8#
12011	6/24	7°04′	56°22′	35	30	81	76	1	Pink spotted	62	Grunt 24#, Snapper 18#, Bumper 8#
12012	6/24	6°57′	56°22′	30	30	81	77	3	Pink spotted	64	Snapper 15#, Grunt 13#, Bigeye 9#
12013	6/24	6°50′	56°25′	24	30	80	77	0	—	4	Grunt, Goatfish
12014	6/25	6°30′	56°35′	20	30	79	78	7	Pink spotted	91	Filefish 29#, Goatfish 15#, Grunt 8#
12015	6/25	6°26′	56°38′	17	60	79	79	18	Pink spotted	137	Seatrout 31#, Sand Perch 24#, Goatfish 14#, Filefish 13#
12016	6/25	6°16′	56°09′	15	60	79	78	1	Brown	131	Sea Catfish 62#, Drum 28#, Seatrout 6#
12017	6/25	6°37′	55°58′	20	60	80	77	<1	Pink spotted	148	Pigfish 37#, Grunt 27#, Goatfish 20#, Filefish 10#
12018	6/26	6°52′	55°54′	25	30	80	77	3	Pink spotted	58	Goatfish 26#, Filefish 11#, Snapper 10#
12019	6/26	6°58′	55°53′	30	37	80	76	5	Pink spotted	62	Snapper 11#, Bumper 9#, Flying Gurnard 6#
12020	6/26	7°05′	55°26′	35	34	81	76	11	Pink spotted	116	Snapper 76#, Bumper 5#
12021	6/26	7°01′	55°26′	30	30	81	75	8	Pink spotted	52	Snapper 31#, Goatfish 8#
12022	6/26	6°49′	55°29′	25	30	80	76	13	Pink spotted	103	Pigfish 28#, Goatfish 20#, Triggerfish 17#
12023	6/27	6°35′	55°33′	20	60	80	77	5	Pink spotted	245	Pigfish 98#, Goatfish 45#, Seatrout 28#, Snapper 13#
12024	6/27	6°16′	55°36′	15	60	79	77	6	White	339	Sea Catfish 119#, Drum 65#, Seatrout 48#
12025	6/27	6°23′	54°59′	15	30	79	76	1	Brown	364	Sea Catfish 246#, Drum 95#, Seatrout 15#
12026	6/27	6°36′	54°57′	20	30	79	76	9	Pink spotted	144	Croaker 48#, Pigfish 40#, Snapper 15#, Grunt 10#
12027	6/27	6°49′	54°88′	25	60	80	75	7	Pink spotted	116	Goatfish 48#, Lizardfish 10#, Seatrout 10#
12028	6/28	7°02′	55°00′	30	60	80	77	8	Pink spotted	74	Snapper 24#, Goatfish 20#, Seatrout 7#, Blackear Bass 6#
12029	6/28	7°11′	55°00′	35	60	81	74	4	Pink spotted	70	Snapper 28#, Searobin 9#, Lizardfish 9#
12030	6/28	6°59′	54°36′	35	30	81	73	9	Pink spotted	81	Snapper 32#, Cusk-eel 10#, Searobin 10#
12031	6/28	6°51′	54°26′	30	30	81	73	2	Pink spotted	41	Cusk-eel 13#, Flounder 6#
12032	6/28	6°46′	54°27′	25	30	80	73	3	Brown	50	Cusk-eel 13#, Seatrout 10#, Searobin 10#
12033	6/28	6°34′	54°28′	20	60	80	74	2	Brown	25	Seatrout 12#, Croaker 6#
12034	6/29	6°21′	54°28′	15	60	80	74	1	Brown	18	Seatrout 17#
12035	6/29	6°18′	53°58′	15	30	79	78	4	Brown	83	Seatrout 18#, Croaker 5#, Grunt 37#, Goatfish 8#
12036	6/29	6°21′	53°57′	15	60	80		17	Pink spotted	37	Flatfish 9#, Grunt 21#, Lizardfish 5#
12037	6/29	6°32′	53°58′	25	60	80	75	34	Pink spotted	200	Triggerfish 18#, Bumpers 16#, Goatfish 134#, Flatfish 8#
12038	6/30	6°49′	53°58′	30	60	80	74	21	Brown	94	Seatrout 5#, Goatfish 39#, Lizardfish 4#, Moonfish 14#, Flatfish 3#
12039	6/30	6°54′	53°58′	35	60	80	73	12	Brown	128	Wenchman 10#, Seatrout 2#, Cusk-eels 11#, Searobin 19#, Seabass 38#, Flatfish 17#, Lizardfish 6#
12040	6/30	6°52′	53°26′	35	30	82	73	5	Pink spotted	65	Wenchman 11#, Triggerfish 8#, Midshipman 9#, Goatfish 3#
12041	6/30	6°28′	53°21′	30	30	81	74	4	Pink spotted	69	Wenchman 2#, Triggerfish 51#, Midshipman 5#, Flatfish 4#
12042	7/1	6°12′	53°30′	25	30	80	76	12	Brown	56	Wenchman 4#, Flatfish 10#, Goatfish 16#
12043	7/1	6°05′	53°30′	22	60	80	77	25	Brown	44	Flatfish 10#, Cusk-eels 4#, Butterfish 12#, Midshipman 10#
12044	7/1	5°58′	53°23′	20	30	78	77	3	Pink spotted	238	Seatrout 4#, Drum 150#, Pigfish 50#, Flatfish 6#
12045	7/1	5°38′	52°52′	22	53	83	77	107	Brown	225	Drum 74#, Seatrout 7#, Snapper 5#, Pigfish 54#, Searobin 12#, Flatfish 22#, Lizardfish 10#

12046	7/1	5°46'	52°51'	24	60	83	76	32	Brown	105	Flatfish 83#, Lizardfish 4#
12047	7/1	6°00'	52°51'	30	60	82	75	1	Pink spotted	232	Cowfish 13#, Triggerfish 49#, Grunt 7#, Flatfish 30#, Goatfish 3#
12048	7/2	6°06'	52°52'	35	90	82	76	9	Pink spotted	183	Wenchman 3#, Triggerfish 65#, Searobin 9#, Goatfish 85#
12049	7/2	5°56'	52°26'	35	30	84	75	21	Pink spotted	103	Wenchman 6#, Triggerfish 44#, Grunt 7#, Pigfish 9#, Flatfish 10#, Goatfish 8#
12050	7/2	5°50'	52°22'	30	30	83	75	12	Pink spotted	56	Snapper 21#, Triggerfish 6#, Goatfish 8#
12051	7/2	5°27'	52°28'	25	55	82	75	27	Pink spotted	319	Snapper 30#, Cowfish 14#, Triggerfish 5#, Porgies 4#, Grunt 23#, Pigfish 195#, Flatfish 17#, Searobin 5#
12052	7/3	5°20'	52°22'	20	60	82	75	18	Brown	70	Seatrout 4#, Drum 17#, Sea Catfish 6#
12053	7/3	5°18'	52°22'	15	30	82	75	10	Brown	54	Snapper 2#, Seatrout 16#, Drum 23#, Pigfish 6#, Searobin 9#, Flatfish 4#
12054	7/3	4°59'	51°58'	18	33	82	76	2	Brown	438	Seatrout 33#, Drum 337#, Catfish 46#, Grunt 10#
12055	7/3	5°04'	51°54'	22	60	83	75	28	Brown	105	Seatrout 36#, Drum 36#, Goatfish 4#, Grunt 15#
12056	7/3	5°06'	51°53'	30	30	83	75	11	Brown	20	Midshipman 12#, Goatfish 1#
12057	7/3	5°14'	51°54'	30	30	83	76	2	Brown	218	Snapper 16#, Seatrout 7#, Cowfish 41#, Bonefish 13#, Spadefish 43#, Pigfish 69#
12058	7/4	5°24'	51°54'	35	30	83	75	2	Brown	28	Flatfish 9#, Lizardfish 4#, Cowfish 4#
12059	7/4	5°43'	51°15'	100	120	84		<1	—	89	Small Catch, Searobin 1#
12060	7/4	5°13'	51°30'	35	30	83	74	25	Brown	23	Boarfish 1#, Flatfish 19#
12061	7/4	5°01'	51°30'	32	30	84	75	2	Pink spotted	183	Snapper 14#, Triggerfish 34#, Pigfish 51#
12062	7/4	4°50'	51°29'	29	60	84	76	8	Brown	247	Snapper 11#, Seatrout 102#, Pigfish 68#, Threadfins 10#, Flatfish 7#

Figure 2.—Catch of shrimp *(Penaeus brasiliensis)* and fish on deck of RV *Oregon II*. This photograph is typical of the catches made during cruise 38.

Figure 3.—The conveyor/processing facility on deck of RV *Oregon II*. The facility transports the catch by conveyor belt to the adjacent interior laboratory.

salinities were taken at the beginning and end of each fishing station.

All drags were made at night (between dusk and dawn) and were generally of 30- or 60-minute duration. The catches consisted of mixed shrimp and fish (Figure 2). The catches were sorted by species and the number and weight of each species were determined (Figures 3 and 4). In addition the length and sex of all commercial shrimp were recorded. Details of the catches are shown in the fishing log (Table 1).

SHRIMP

A total of 637 pounds (heads-on) of shrimp were caught at the 67 fishing stations. This catch included 340 pounds of brown shrimp *(Penaeus aztecus subtilis)*, 268 pounds of pink spotted shrimp *(Penaeus brasiliensis)*, 25 pounds of pink shrimp *(Penaeus duorarum notialis)*, and 4 pounds of white shrimp *(Penaeus*

Figure 4.—Sorting of the trawl catch into species categories. The numbers and weights of each species were recorded.

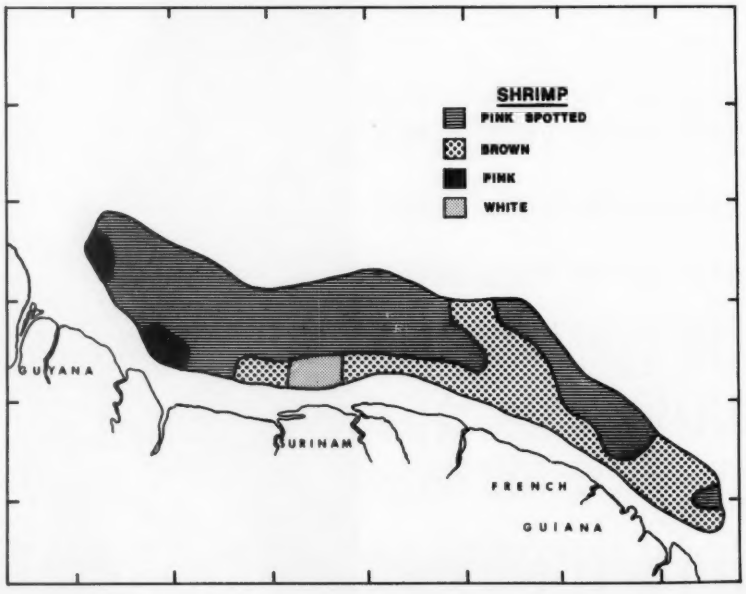


Figure 5.—Distribution of shrimp off Guyana, Surinam, and French Guiana in June-July 1972 (*Oregon II* cruise 38). The species of shrimp which predominated in the catches is shown for the area of the survey.

Figure 6.—Feeding frenzy behavior of large sharks near Devil's Island, French Guiana. The sharks were chummed to the boat with trash fish.

schmitti). The catch rates were generally low, owing partially to bright moonlight nights. The maximum catch rate of shrimp was 120 pounds per hour but the average catch was only 14 pounds per hour.

The four species of commercial shrimps had distinct distribution patterns (Figure 5). The pink spotted shrimp dominated the catches off Guyana and Surinam, and the brown shrimp dominated the catches off French Guiana. However, both species were caught on all the transects between Georgetown and Cabo Orange. Brown shrimp were generally most abundant in the catches from 25 fathoms or less while pink spotted shrimp were mostly restricted to the area off Guyana and western Surinam. White shrimp were taken only at the shallow water stations in the region of Paramaribo.

Maximum catch rates by species of shrimp were as follows: pink spotted shrimp, 30 pounds (heads-on) per hour; brown shrimp, 120 pounds; pink shrimp, 36 pounds; and white shrimp, 4 pounds. The average sizes of shrimp in the above maximum catches were: pink spotted shrimp, 9.8 per pound (heads-on); brown shrimp, 17.6; pink shrimp, 8.6; and white shrimp, 8.3.

FISH

Maximum catch rates of fish occurred in 15 to 18 fathoms between Paramaribo, Surinam, and Cayenne, French Guiana. The predominant fishes in these catches were sea trout *(Cynoscion),* croakers *(Micropogon),* and catfishes *(Ariidae).* In 20 to 35 fathoms throughout the survey area a variety of tropical species occurred. The deeper stations produced incidental catches of Caribbean red snapper *(Lutjanus purpureus)* and lane snapper *(L. synagris).* Grunts *(Haemulon)* were often the dominant finfish present at depths greater than 20 fathoms. Large numbers of carcharhinid sharks (mostly blacktip sharks with some bull sharks and sharpnose sharks and occasional very large unidentified sharks) were present throughout the survey. Off Devil's Island, French Guiana, sharks were easily chummed into a feeding frenzy (Figure 6).

MFR Reprint 970. From Marine Fisheries Review, *Vol. 35, Nos. 3-4. Copies of this reprint, in limited numbers, are available from D83, Technical Information Division, Environmental Science Information Center, NOAA, Washington, DC 20235.*

MFR REPRINT 971

Shrimp Industry of Central America, Caribbean Sea, and Northern South America

GEORGE B. GROSS

INTRODUCTION

The warm-water shrimp fishery of the Western Hemisphere can be divided naturally into six areas that have a minimum of overlap: (1) the South Atlantic Coast of the United States; (2) the Gulf of Mexico (United States and Mexico); (3) the Pacific coast of Mexico; (4) the Pacific coast from Guatemala to Ecuador, inclusive; (5) the Caribbean Sea; and (6) the Atlantic coast of northeastern South America. The present report describes the fisheries of the last three named areas.

The fishery on the Pacific coast of Central America began at Panama and spread both north and south, whereas the Caribbean and Guiana fisheries are outgrowths of United States fishing in the Gulf of Mexico. U.S. fishermen, vessels, plant operators, importers, and investors have been involved in nearly all the shrimp fisheries in Latin America. There has also been some participation by French, Japanese, Portuguese, and Mexicans. To a considerable extent local personnel and investment have replaced the foreign involvement.

The shrimp fisheries of Latin America are based on numerous species of large warm-water shrimps of the genus *Penaeus*, generally of three types: white, brown, and pink. Commercially most important on the Pacific side are three white species, one brown, and one pink. The Atlantic and Gulf coasts have two white species, two brown, and one pink that dominate the catches.

Although priced somewhat differently and attaining varying maximum sizes, all are readily acceptable to the U.S. consumer.

In some areas, several smaller species of shrimp, known as sea bobs, are abundant. They are taken in growing amounts as new markets for them are being developed. Although the larger penaeid shrimps dominate the fishery, the sea bobs form a resource in reserve for future use.

All the white, brown, and pink shrimps have similar life histories, and their occurrence in significant quantities depends on their strict habitat requirements. They spend their adult lives on muddy sea bottoms in depths of 1 to 50 fathoms, depending on the species. They spawn at sea. The very young shrimp move into coastal lagoons or estuaries where they spend varying periods of time in brackish water. As subadults they move from the lagoons to nearby ocean waters, where they finish out their life span of a little over a year. Hence, fishing areas are confined to open waters over a mud bottom that are adjacent to large brackish lagoons, and to the lagoons themselves. A classic example is the tremendous nursery area of Lake Maracaibo, Venezuela, where the subadult shrimp are harvested in the lake by beach seines and cast nets, and the large shrimp are taken by trawling in the adjacent open waters of the

George B. Gross is Regional Fisheries Attache for Latin America, assigned to the U.S. Embassy in Mexico. **This report was originally issued in a limited edition as Foreign Fisheries Leaflet No. 73-1 by the NMFS International Activities Staff.**

Gulf of Venezuela. No substantial shrimp fisheries have been developed over rocky or clean sand bottoms, nor distant from brackish water lagoons.

On the Pacific coast, the large penaeid shrimps are found in a relatively continuous band all along the coast from northern Mexico to northern Peru, with only a few gaps along stretches of rocky and sandy shores. On the Atlantic side they are found from the southern coast of the United States to Brazil, including the Gulf of Mexico and the Caribbean Sea. However, they are not plentiful along the shores of the Greater and Lesser Antilles, and there seem to be long gaps in their occurrence in apparently favorable areas along the mainland coast of the Caribbean.

Throughout this report, weights are given in pounds, and prices and values are expressed in U.S. dollars. Although most of the countries in the area use the metric system of weights and have different currencies, the industry is tied so closely to U.S. practices and the U.S. market that even the fishermen and plant workers talk in terms of pounds and dollars.

THE SHRIMP FISHERY OF THE PACIFIC COAST OF CENTRAL AND SOUTH AMERICA

General

Shrimp fishing on the Pacific coast started in northern Mexico as early as 1941, but it was not until the 1950's that any large-scale fishing began elsewhere on the coast. Commercial shrimp fishing in Panama began in 1950 and within a few months had become an important industry.

The Panamanian industry expanded so rapidly that many producers left for less crowded waters. From Panama, the industry spread south to Colombia and Ecuador, particularly the latter, as U.S. operators expanded their operations. Development northward was somewhat slower, although small-scale operations began in Costa Rica as early as 1952 and had expanded considerably by 1958, when the commercial fishery in El Salvador began. Development of the fisheries in Guatemala and Nicaragua followed. Meanwhile, the Mexican fishery in the Gulf of Tehuantepec developed in the early 1950's and reached its peak in 1959.

As of 1972, the shrimp fishery of the Pacific coast from Mexico to Ecuador has been developed to about maximum capacity, with the following possible exceptions:

a. Fishing in deeper water principally for pink shrimp, could increase production in some areas;
b. Greater utilization of the smaller species of shrimp (as in Panama) could increase landings in Central America;
c. Development of suitable smallcraft harbors would result in the expansion of the fishery in Guatemala;
d. Use of larger boats and additional ports could result in an increase in Costa Rican production; and
e. Catches in Colombia could be increased if more vessels were permitted to enter the fishery.

Otherwise, harvesting of known shrimp stocks appears near maximum, and future fluctuations in catches will be due to changes in the natural abundance of shrimp, or to changing market conditions.

Shrimp are found in commercial quantities along most of the Pacific coast of Central America. The Guatemala grounds are actually an extension of the Mexican grounds in the Gulf of Tehuantepec. In fact, several incidents have occurred involving the trawlers of both countries fishing off the coast of the other as fishing success varies north or south of the border. In turn, the Guatemala grounds merge into those off El Salvador, which are probably the most productive of any along the Central American coast. Surprisingly, the Gulf of Fonseca produces little shrimp. Accordingly, Honduras, which faces the Pacific on only part of the Gulf, has only a small-scale fishery. The Nicaraguan coast, lacking suitable lagoons and offshore habitat, contributes in only a minor way to the total production. Costa Rican fishing grounds are mostly in or near the Gulf of Nicoya, but relatively unused grounds exist in the Gulf of Dulce. The highly productive fishery of Panama is located in the Gulf of Chiriqui and the Gulf of Panama. Shrimp are caught along most of the Colombian coast, particularly near Buenaventura. Ecuador's most important shrimp grounds are near Esmeraldas and in the Gulf of Guayaquil.

Along the Pacific coast, the large white shrimp is dominant. Actually the "white" shrimp consists of three species: *Penaeus stylirostris* (sometimes also called blue shrimp), *P. vannamei*, and *P. occidentalis* (the most important species in Panama, Colombia, and Ecuador). The latter two are sometimes dark in color and are then called brown shrimp, along with *P. californiensis*, the true brown. The pink shrimp, *P. brevirostris*, is of considerable importance in El Salvador and Panama. This deeper water species is fished when it is plentiful and readily available (during dry season). This time coincides with the time when whites are not plentiful. The whites are larger and command a higher price.

In addition to the big penaeid shrimps, which are the mainstay of the export shrimp industry, significant quantities of four species of smaller shrimps contribute to the catches, particularly in El Salvador, Panama, Ecuador, and Costa Rica. These are: the purplish brown *Xiphopenaeus riveti* and the yellow and orange *Protrachypene precipua*, which are known as sea bob or "titi;" and *Trachypenaeus byrdi* and *T. faoe*, which are variously called "tigre," "indio," "zebra" (or "cebra"), and "carabali." In some areas, all the small shrimps are collectively called "chacalin"; elsewhere they are known as "camaroncillo."

Guatemala

Guatemala has a Pacific coastline of about 155 miles. The two ports, Champerico and San Jose, are open, unprotected roadsteads with piers but no harbors. Champerico is about 25 miles from the Mexican border. San Jose is about 80 miles to the southeast, some 50 miles from the border with El Salvador. Both towns are shrimp ports.

Shrimp are fished along the entire coast, except for a few rocky spots. The fleet based in Guatemala ranges all the way from the Mexican border to El Salvador. Guatemalan vessels sometimes fish beyond the frontiers, and vessels from the neighboring countries stray at times into Guatemalan waters.

At the end of 1970, Guatemala's shrimp fleet consisted of 26 vessels, 20 fishing out of Champerico for Pesca, S.A., and 6 fishing out of San Jose for El Ganadero, S.A., a new firm that entered the shrimp business in May 1970. Both companies are increasing their production of peeled and deveined shrimp.

Neither Champerico nor San Jose has a harbor, which means that lightering is required between shrimp boats anchored in the open sea and the commercial piers at the two ports. This causes delays, inconvenience, and high costs.

The Guatemalan Government is studying plans for a protected harbor, probably at Champerico, but construction is 5 to 10 years away.

The operation at Champerico is a joint venture of two companies, each of which owns 10 boats. Pesca, S.A., and Copeagua, S.A., operate the freezing plant at Champerico and share a headquarters office in Guatemala City. The ownership of both companies is 51 percent Guatemalan and 49 percent Japanese (Mitsubishi and Nichiro). Sharing management with Guatemalans are two Japanese in Guatemala City and several in Champerico, all of whom live in Guatemala with their families.

Fishing trips are generally 12 or 13 days. The boats occasionally fish out to 55 fathoms, but most stay inside 35 fathoms. The catches are principally whites (blancos) and pinks (rojos). The whites are *Penaeus stylirostris* and *P. vannamei*. The whites and pinks are both seasonal, and alternately predominate in the catches. Because of the high cost of operations, the lower priced sea bobs are fished only when the large shrimp are scarce.

Exports destined for the eastern United States are shipped by refrigerated truck-and-trailer to the new port at Puerto Matias de Galvez on Guatemala's Caribbean coast, and thence direct to Miami on the trailer ferry. Shipments for the United States and Canadian Pacific coast and Japan go directly from Champerico by steamer. The distributor in the Miami area is Latin American Distributors, Inc. Mitsubishi International, Inc., handles distribution on the Pacific coast and in Japan. Puerto Rico is a growing market for Guatemalan shrimp; Cerra Commercial is the distributor.

Table 1.—United States imports of shrimp from Guatemala, 1961-71

Year	Volume	Value
	1,000 pounds	*$1,000 U.S.*
1961	743	405
1962	2,298	1,491
1963	1,943	1,062
1964	2,207	1,135
1965	1,515	962
1966	2,481	1,968
1967	1,924	1,589
1968	1,315	1,135
1969	1,693	1,705
1970	2,948	2,796
1971	2,338	2,392

El Salvador

The fishing grounds that lie off the 175-mile coastline of El Salvador produce more shrimp than any comparable area between Mexico and Panama. The otherwise undistinguished little tropical village of El Triunfo is one of Central America's most active shrimp ports.

From northwest to southeast, the four fishing ports of El Salvador are Acajutla, La Libertad, Puerto El Triunfo, and La Union. Of these, the first two support only small-scale fresh-market fisheries, whereas the latter two are primarily shrimp ports. The shrimp trawling grounds extend along most of the ocean coast; those in the eastern half are the most extensive. Very few shrimp are taken in the Gulf of Fonseca in the eastern part of the country.

Although it had long been known that there were shrimp off El Salvador, no serious effort was made to fish them commercially until 1955. Previously, the only shrimp fishery was in the lagoons and estuaries where canoe fishermen took juvenile shrimp with cast nets and traps. Although the "inside" fishery still exists, it has diminished as the fishermen have turned to trawling in the ocean.

Following initial studies by foreign experts, the Government limited shrimp fishing to 18 vessels. As a result of further surveys that showed very large populations of shrimp, the limit was raised to 73 vessels in 1962. This limit was still in effect in December 1971.

The first exports of shrimp to the United States began in late 1957 and grew rapidly. The industry was, and is, well organized, has governmental support, uses only good vessels and plant equipment, and has established high-quality standards from the start. Consequently, it has thrived ever since its inception.

The $4 to $5 million of foreign exchange earned by the shrimp industry is important to the economy of El Salvador. Shrimp ranks third in importance, behind coffee and cotton, among nonmanufactured exports from El Salvador. The government receives substantial revenue from the export tax of 6 cents per pound.

The center of shrimp industry is Puerto El Triunfo, a small village on a large lagoon known as Bahia de Jiquilisco that opens into the ocean about 125 miles south of Guatemala and 35 miles west of the Gulf of Fonseca. The principal shrimp trawling areas lie within 10 miles of the coast and extend 40 miles west and 30 miles east from the entrance to the lagoon, which is one of the principal nursery areas for young shrimp.

The two shrimp freezing plants in El Triunfo supply nearly all El Salvador's production. Pezca, S.A., handles 80 percent of the national pack and is one of the largest and best equipped plants in Latin America. It is located on a mangrove marsh, and the boats unload at a pier that traverses the tide flats. Pickup trucks transport the shrimp in metal tubs from dockside to plant. Pezca is constantly adding new equipment. In June 1965 it began operating the most modern peeler-deveiner for producing individually quick frozen (I.Q.F.) peeled and deveined shrimp. The machine is used for sea bobs and the smaller sizes of white, brown, and pink shrimp. Some of the larger sea bobs are prepared "butterfly" style. Pezca is owned and operated jointly by Portuguese and Salvadoran interests, with some Panamanian capital.

Atarraya, the other plant in El Triunfo, is equally modern and well equipped but lacks a peeler-deveiner. The plant has a complicated three-way ownership and management, and any or all of three names are used on equipment, trucks, and packages: Atarraya, S.A.; Congeladora Ballena, S.A.; and Consolidated Sea Foods of New York. Most of the capital is Salvadoran. This

plant is making a special effort to develop a domestic market, particularly for frozen and packaged sea bobs, and reports good success.

The other shrimp plant in El Salvador is located at La Union on the Gulf of Fonseca. Pesquera Nacional, S.A., is affiliated with another plant with a similar name in Puerto Somoza, Nicaragua, and at one time froze and packed shrimp for that concern, until the Nicaraguan company built its own freezer.[1] Because La Union is located on a shallow bay it was necessary to construct a long pier for the trawlers. La Union is rather far from the trawling grounds, which lie to the west on the open coast. Surprisingly, there is little or no shrimp fishing in the Gulf of Fonseca.

The ownership of the Salvadoran shrimp fleet is divided among 15 fishing companies. By law, only vessels of Salvadoran ownership and registry may fish shrimp within the 200-mile fishery zone claimed by El Salvador. The number of boats per company varies from one to 12 (the legal limit for any one company); the two largest packing companies own the largest fleets. The other fishing companies are owned by corporations or individuals, many of whom are associated with the packing plants. As noted above, the total number of vessels is limited to 73. Some of the licensed boats are inactive for one reason or another; at any one time the number of boats in actual operation averaged 71 during 1970-71.

In practice, the vessels fishing for the plants at El Triunfo operate as two fleets, one for each plant, even though many owners are involved. Sixteen vessels fish for Atarraya, and over 40 deliver to Pezca, all equipped with brine tanks.

Pezca and Atarraya jointly built and operate a boatyard across the bay from El Triunfo. The yard has marine ways, shops, and a parts depot. The vessels of both fleets undergo regularly scheduled overhauls.

The white shrimp are seasonal in abundance in the areas now fished by the fleet. In general, the fleet concentrates on white shrimp from October through April and avoids pinks during that time. The catch-per-day for whites is highest in October to March, and the best months are November through February. However, the largest whites are taken in April to July when the catches of that species are lowest.

All of the large white, pink, and brown shrimp go by the general name of "camaron." The juveniles of all species, when caught in the lagoon fishery, are called "chacolin." The proportions of the three white shrimp (known as "blancos") vary greatly from time to time; the average percentages are: *Penaeus vannamei*, 46; *P. stylirostris*, 31; and *P. occidentalis*, 23. The pink shrimp, known in El Salvador as "rojos," consist almost entirely of *P. brevirostris*. All of the brown shrimp, which are called "cafe," are brown specimens of the white shrimp, *P. occidentalis*.

The sea bobs taken in El Salvador consist of four species, all called "camaroncillo" by the industry. Two of the species, *Trachypenaeus byrdi* and *T. faoe*, are indiscriminately called "tigre," "carabali," or "cebra." The two smaller species, which are often discarded at sea, are the "titi," *Xiphopenaeus riveti*, and the "pomada," *Protrachypene precipua*.

Based on careful sampling at the plants, the Fisheries Section, Ministry of Economy, has calculated the catches of the various species by the trawl fleet in the past 10 years (Table 2):

As noted above, the domestic market for shrimp, particularly sea bob, is growing rapidly. The following amounts of sea bobs and regular shrimp taken by the trawl fishery were sold mostly in San Salvador (Table 3).

The outlook for the shrimp industry of El Salvador is excellent. It should be possible to maintain the production of white and brown shrimp with the present fleet. Some observers favor cutting the number of vessels, believing a smaller fleet could catch the same amount more profitably. Some in industry believe the present flat-rate export tax of 6 cents should be modified to provide for a lower tax on the lower priced small sizes. They argue that there is now no incentive to produce pinks and sea bobs, and only a tax cut will result in better utilization of these species. A new tax structure is under study.

Honduras

Honduras has no developed shrimp fishery on the Pacific nor is one likely, since Honduras has no coastline on the open ocean. Its entire 40 miles of coast lie at the head of the Gulf of Fonseca. Although the tributary estuaries are nursery grounds for juvenile shrimp,

Table 2.—El Salvador shrimp catches, heads off weight, 1961-70

Year	White	Pink	Brown	Large shrimp subtotal	Sea bob	All species total
			Thousand pounds			
1961	3,856	1,652	960	6,468	2,037	8,505
1962	3,485	1,212	254	4,951	3,310	8,261
1963	3,632	1,054	205	4,891	2,820	7,711
1964	3,851	831	228	4,910	2,715	7,625
1965	2,338	966	143	3,447	3,503	6,950
1966	3,497	1,090	207	4,794	5,288	10,082
1967	2,313	922	174	3,409	4,299	7,708
1968	2,217	786	152	3,155	2,987	6,142
1969	2,515	813	200	3,528	3,567	7,095
1970	2,336	913	387	3,636	4,772	8,408

Table 3.—Local sales of shrimp and sea bobs in El Salvador, 1963-70

Year	Sea bobs	Regular shrimp
	1,000 pounds	*1,000 pounds*
1963	27,000	—
1964	269,000	—
1965	267,000	66,000
1966	135,000	120,000
1967	110,000	5,000
1968	441,000	121,000
1969	442,000	410,000
1970	—	1,508,000

(The tremendous increase in 1968-70 is attributable to the growth of retail supermarket outlets in San Salvador).

Table 4.—United States imports of shrimp from El Salvador, 1961-71.

Year	Volume	Value
	1,000 pounds	*$1,000 U.S.*
1961	8,093	5,505
1962	7,156	4,982
1963	6,667	4,279
1964	6,296	3,918
1965	5,376	3,581
1966	6,955	5,431
1967	6,724	5,626
1968	4,639	4,236
1969	5,026	5,069
1970	6,689	5,521
1971	6,707	6,155

[1] In 1970 this company operated six boats.

the Honduran portion of the gulf has no suitable trawling grounds.

El Salvador and Nicaragua have jurisdiction over most of the outer part of the gulf and over the ocean coastline on either side, and their laws do not permit fishing by foreign-based boats.

A subsistence fishery has always existed along the shores of the gulf and in the tributary estuaries and lagoons, using cast nets for juvenile white shrimp. In 1956 the annual catch was estimated at 50,000 pounds, heads-on weight.

Nicaragua

Nicaragua has a Pacific coastline of about 190 miles. Three ports are available for shrimp operations: Corinto in the north; Puerto Somoza, about 65 miles down the coast; and San Juan del Sur, near the Costa Rican border.

Shrimp are found along the entire coast. However, rocky bottom near shore limits the boats to depths greater than about 10 fathoms along much of the coast. In most of their range, the white shrimp are fished heavily in less than 10 fathoms; hence the unsuitable bottom near shore probably limits the catch.

The extent of the Nicaraguan shrimp fishery is indicated by United States Customs figures on imports (Table 5), because practically all the production is exported to the United States. The following table shows imports of shrimp from both coasts. The figures are mostly heads-off, shell-on weights; however, an increasing proportion is shipped peeled and deveined.

The plant at Corinto established by other interests some years ago was in 1971 operated under the name ALINSA, a 100 percent Nicaraguan-owned company. The production averages about one million pounds of shrimp per year, plus 100,000 pounds of fish for local consumption.

Table 5.—United States imports of shrimp from Nicaragua, 1961-71

Year	Volume	Value
	1,000 pounds	*$1,000 U.S.*
1961	803	341
1962	1,971	979
1963	1,611	889
1964	2,520	1,786
1976	3,154	2,296
1966	3,914	3,147
1967	5,053	4,148
1968	5,626	5,049
1969	7,206	6,833
1970	6,146	6,021
1971	5,639	6,915

The fleet at Corinto consists of nine modern steel trawlers, plus 10 older boats individually owned, all under Nicaraguan flag. A parts depot and service facility recently have been added. Annual production of the newer steel boats averages about 85,000 pounds per boat.

The fishing grounds extend from the Gulf of Fonseca south to San Juan del Sur. The estimated annual production of these grounds, including "titis" and pinks, is 3.6 million pounds.

Most of the large shrimp or "camarones" are whites. All three species are caught. *Penaeus occidentalis* and *P. stylirostris*, both known locally as either "white #1" or "white #2", are taken only in the large sizes. They run mostly under 10 to the pound, with some 11 to 15.[2] The fishery takes all sizes of *P. vannamei*, which is called "blanco" only; about 40 percent are 16 to 20, the rest smaller. All three species are packed together; sorting is based only on size.

Some of the large shrimp are browns, *P. californiensis*, called "cafe." There are two color phases, brown and white. They are taken in all sizes. Most are under 30 per pound, many are under 10.

Pinks are called "rosados," *P. brevirostris*. Increasing quantities are being fished.

Two species of "camaroncillos" are taken, the "titi," *Xiphopenaeus riveti*, and the "tigre," *Trachypenaeus byrdi*. Both are called "chacalin" in the Gulf of Fonseca.

San Juan del Sur has a new plant called NICAMAR, operated by Booth Fisheries, with a daily capacity of 20,000 pounds and a fleet of 14 steel trawlers. Average annual production of this plant is 1 million pounds.

All shrimp operations, for export, are under exclusive concessions granted by the government. The concessions are granted only to companies owned partly by Nicaraguans and which can demonstrate that they are physically and financially capable of operating. The concessionaires may import boats, machinery, parts, and equipment duty-free. The vessels may remain under their own flag, as long as they fish for the concessionaire. If the owners desire, they may transfer to Nicaraguan registry. Local fishermen who wish to fish for shrimp (except for domestic consumption) must deliver their catches only to the concessionaires.

The export tax on all shrimp, regardless of size or species, is 3 cents a pound.

Present indications are that Nicaraguan's Pacific coast fishery can produce about 3 million pounds of shrimp and 50,000 pounds of lobsters annually. Local industry sources report "unlimited" quantities of shrimp considered too small for the present commercial market. Deep-water red shrimp have been caught occasionally, and exploratory work is being carried on for this species, which is reported to average about 100 tails to the pound.

[2]Number of shrimp per pound pertain to shrimp with heads-off.

Costa Rica

The Pacific coastline of Costa Rica differs from the coasts of the Central American countries to the north in several respects. First, it is by far the longest, over 360 miles. Second, it is broken by a series of peninsulas and gulfs, unlike the virtually straight coast of the other countries. Finally, in all its length, Puntarenas, which is located midway between the borders with Nicaragua and Panama, is the only fishing port of any consequence. Although Golfito in the south has potentialities for fishing it is now only a shipping point for bananas.

Shrimp are found along most of the coast, but the fishing grounds are interrupted by stretches of rocky bottom. Although it has a long coastline, its fishing area is determined by the size of the Continental Shelf. In this respect, unfortunately, Costa Rica is one of the poorest in Central America. The narrow shelf explains why Costa Rica does not produce half as much shrimp as the much smaller El Salvador. The extensive Gulf of Nicoya is the center of abundance. Other grounds are to the south in the open Bay of Coronado and in the Gulf of Dulce. Elsewhere, the precipitous nature of the coastline limits both nursery grounds and trawl-

ing areas. The inner part of the Gulf of Nicoya is reserved as a nursery area for juvenile shrimp, and trawling therein is prohibited.

Only Costa Rican boats may fish for shrimp. Until recently, all new boats had to be constructed in Costa Rica with domestically produced materials, but new laws now permit the importation of steel hulls provided the superstructure is built in Costa Rica.

The following data show the rapid growth of the active fishing fleet in the last 5 years:

	1965	1970
Large vessels (56-75 feet)	15	35
Medium vessels (45-55 feet)	22	16
Small vessels (30-44 feet)	15	10
	52	61

All of the large vessels fish with nets in the typical double outrigger manner. Each is equipped with depth finders. All 16 medium-sized vessels fish two nets, and 12 have depth finders. Most of the small boats still fish single nets and make a relatively small contribution to total production.

The boats are owned by local fishing companies and the Borden Company, and modernization of others has brought the fleet up to the efficient standards of neighboring countries. The improvement of vessels capable of fishing in deeper water and farther from port, has increased production to about its natural limit.

The several boatyards in Puntarenas not only build shrimp boats but provide adequate maintenance service for the fleet.

A smaller freezing plant, locally owned, is Compania Industrial de Mariscos. An American firm, Henderson Portion Pak, which became an affiliate of Borden Foods in 1965, is planning to enlarge its already modern freezing plant.

Table 6 shows the growth in Costa Rica's export shrimp industry.

Shrimp taken for export are predominantly large whites. By far the most important species is *Penaeus occidentalis*. In 1959 this species accounted for about two-thirds of the production of whites. The remaining one-third was almost all *P. stylirostris*, with a very few *P. vannamei* and *P. californiensis*. The industry and the fishermen do not distinguish between the species, which are all called whites ("blancos") or large shrimp ("grandes"). The whites run from 40/50 to 7 to the pound; most are 10/15 and 16/20.

Table 6.—United States imports of shrimp from Costa Rica, 1961-71.

Year	Volume	Value
	1,000 pounds	*$1,000 U.S.*
1961	1,620	743
1962	1,738	786
1963	1,790	766
1964	2,471	1,133
1965	1,753	868
1966	1,779	1,070
1967	1,679	1,234
1968	2,351	1,696
1969	1,344	1,107
1970	2,534	1,889
1971	2,323	2,250

Note: The above weights are heads-off, mostly shell-on. Increasing quantities, particularly of the smaller sized shrimp, are shipped peeled and deveined.

In 1960, the fleet began taking pink shrimp, *P. brevirostris*, on a small scale. Extensive grounds for pinks are located north of Puntarenas and in the south near the island of Canas. The production of pinks has doubled since the introduction of modern fishing gear by the new Borden plant. Pinks are considerably smaller than whites, from 16/20 to 70/80, with a considerable proportion at 40/50 and 50/60.

The abundant sea bobs are taken mostly for the domestic market. With the increasing popularity of peeled and deveined shrimp, these small varieties are bound to play a larger part in the export industry. All four species are taken: *Xiphopenaeus riveti, Protrachypene precipua, Trachypenaeus byrdi,* and *T. faoe.* It was estimated in 1959 that the first named of these made up most of the production. All are grouped together by the fishermen and plant operators as "brown shrimp," a terminology not used elsewhere. Government statistics refer to them as small shrimp ("pequenos"). The sea bobs are very small; their tails average 50/70.

Table 7 demonstrates the usual history of the Pacific coast shrimp fisheries: a rapid growth based on production of whites, followed by a partial substitution of pinks when the catches of whites level off. Later the production of sea bobs increases to take care of growing domestic consumption and to augment exports. It would appear that with the present fleet and fishing practices, both catches and exports are about at their maximum.

Costa Rican shrimp are shipped to the United States in a variety of ways. Some are shipped directly from Puntarenas by refrigerated cargo ship. Until recently, most were shipped to Miami by air. Now a considerable portion goes by refrigerated truck and trailer to Puerto Matias de Galvez on Guatemala's Caribbean coast, a road distance of about 935 miles, and thence to Miami by ferry.

The export tax is 2 percent ad valorem, plus about one-quarter of a cent per pound ($0.00226). The ad valorem tax has the effect of an incentive for exporting the smaller, lower priced pink shrimp and sea bob.

In 1970 the American firm Borden Foods began to fish for a new type of shrimp found in deep water (150 fathoms). These shrimp, as yet unidentified, are locally called "camel" and "fidel" and are characterized by a bright pink color. FAO was the first to discover this resource and Borden was the first to use it in an attempt to alleviate the intense fishing effort on shallow water resources. This shrimp is very small (averaging 120/140). Borden hopes to use new processing methods to develop this industry. The processing costs are quite high, but Borden will begin constructing a new plant in 1972 to process this shrimp.

Table 7.—Costa Rican shrimp catches, heads off weight, 1961-69

Year	Large ("blanco")	Pink ("rosado")	Brown ("pequeno"	Total
		1,000 pounds		
1961	848	141	1,211	2,200
1962	604	445	1,228	2,277
1963	671	374	1,362	2,407
1964	1,165	188	1,360	2,713
1965	600	321	1,617	2,538
1966	774	330	1,415	2,519
1967	772	561	1,272	2,605
1968	843	484	2,042	3,369
1969	345	746	1,346	2,437

Panama

The most extensive and most productive shrimp fishing grounds along the Pacific coast south of Mexico are those off Panama. They were also the first south of Mexico to be fished on a large scale. Shrimp are found along most of Panama's sinuous and island-studded coastline of 700 miles, the longest coast under one jurisdiction between Mexico and Peru. The principal fishing grounds are in the Gulf of Panama and the Gulf of Chiriqui, the two principal indentations in the coast. The rocky 100-mile stretch between the two gulfs and the 80-mile stretch near the Colombian border are largely unproductive. Some of the best fishing is within sight of Panama City, and tourists flying in or out of Tocumen International Airport or visiting the ruins of Old Panama can often see the shrimp fleet in action. Panama City is the nation's largest shrimp port, and one of the most important shrimp centers of the world. The other port is Pedregal, the harbor town for David, near the Costa Rican border.

Six freezing plants operate in and near Panama City. All of these are owned entirely by Panamanians. Four are located downtown on the waterfront near the municipal market: Compania de Mariscos Islas de Las Perlas, S.A.; Panama Packing Corporation; Carlos Cambra e Hijos, S.A.; and Cambra Hermanos, S.A. Another, Empacadora Nacional, S.A., is located on the bay at Paitilla in the suburbs. The sixth, Compania de Productos Crustaceos, S.A., is near the mouth of Rio Juan Diaz, close to Tocumen Airport. The plant in David, 230 miles west of Panama City, is Frigorificos de Chiriqui, S.A. This company is a U.S.-owned subsidiary of Henderson Portion Pak, which became affiliated with Borden in 1965. About 200 shrimp vessels operated in 1970; the size of the fleet is controlled by law.

Nearly all of the plant owners, most of the individual boat owners, and some of the boatyards and ship chandlers have organized a national association to promote the fishing industry and to sponsor helpful legislation—Asociacion Nacional de la Industria Pesquera Panamena. Because the fishing industry is centered in the shrimp fishery, which accounts for almost all of its total value, shrimp interests dominate the association. However, the growing fish meal industry is represented and works closely with members from the shrimp industry.

Because the greatest part of the Panamanian shrimp production is exported to the United States, official United States import statistics (Table 8) give an accurate picture of the growth and present size of the industry that provides Panama's second most important export product (bananas being first).

Table 8.—United States imports of shrimp from Panama, 1961-71.[1]

Year	Volume	Value
	1,000 pounds	*$1,000 U.S.*
1961	9,982	6,521
1962	10,117	7,787
1963	10,571	7,164
1964	12,247	8,533
1965	10,264	6,910
1966	9,733	7,875
1967	11,126	9,345
1968	10,730	10,607
1969	9,927	10,171
1970	11,633	11,966
1971	9,316	9,938

[1]Includes Canal Zone production.

The white shrimp include three species which are not separated by the industry, all called "langostinos" or "blancos." *Penaeus occidentalis* is reported to constitute 85 to 90 percent of the catch of whites; the rest of the catch is fairly equally divided between *P. stylirostris* and *P. vannamei*. Some of the *P. occidentalis* are brownish or rusty color and are called "browns" but are not separated.

The pink shrimp, *Penaeus brevirostris*, is known in Panama as "camaron rojo." Most of this medium-sized species ranges from 26 to 50 to the pound; some are as large as 21 to 25. Because of its smaller size, the pink does not command as high a price as the whites and also requires more work in packing. Because it is a deeper water species it costs more to catch. Hence, in Panama, this species is considered as merely a supplement to the white, albeit a valuable one.

Four small species of shrimp or sea bobs, known collectively in Panama as "camarones," constitute an important part of the shrimp catch. Two of these are called "titi": *Xiphopenaeus riveti* and *Protrachypene precipua*. The "titis" are very small, usually 60 or more to the pound, heads-off. All but the largest individuals are packed as peeled and deveined.

The other two small species are *Trachypenaeus byrdi* and *T. faoe*, which are known by the names of "tigre," "carabali," "indio," or "zebra." The "tigres" are slightly larger than the "titi," generally running "under 60" to the pound. Although most of the "tigres" are peeled and deveined, a specialized market exists in Miami for these shrimp with their striped shells intact.

A bright colored "royal red" shrimp is taken in waters somewhat deeper than the similar pink or "rojo." This shrimp, which is probably *Sicyonia florea*, is not particularly desired by the packers because of the poor yield of meat when cooked. However, a considerable potential resource of these "fidels" exists.

All species are taken throughout the fishing grounds, but at different depths. The whites are found close to shore and near islands, at depths from 3 to 15 fathoms, usually along the 12-fathom line. The pinks are taken at about 30 fathoms, with some out to 45 fathoms, especially the "fidels." The "titis" and "tigres" are caught in shallow waters, particularly near river mouths. There has been little exploratory fishing deeper than 50 fathoms. It is possible that the deeper waters have additional resources.

The trawlers based in Panama City fish the entire Gulf of Panama, to a depth of 45 fathoms, from Punta Garachine in the east to Punta Mala in the west, often within sight of the packing plants. When fishing is poor, many of the boats go as far as the Gulf of Chiriqui. The vessels based at David confine their activities to the Gulf of Chiriqui and nearby waters. Even when fishing close to home, the boats make trips of at least 5 to 7 days, and trips to the Gulf of Chiriqui last 10 to 14 days.

Considerable amounts of spiny lobster are taken by the shrimp trawlers, particularly those fishing in and near the Gulf of Chiriqui. The lobsters are headed aboard the boats and delivered along with the shrimp. They were formerly sold on the domestic market. Beginning in 1966, the fishermen improved

the handling techniques to such an extent that the lobsters could meet export standards. Lobsters now constitute a small-scale but valuable fishery.

At present, all the shippers in Panama City send their shrimp to New York City by Grace Line Sea-Trailer. Shipping costs are about 4 cents a pound. Formerly, the plant in David shipped entirely by air, using the northbound, nearly empty, flights of cargo lines that make most of their money hauling southbound general freight. Flights go direct from David to Miami. Later, however, the plant started making shipments by refrigerated trailer to Puerto Matias de Galvez on Guatemala's Caribbean coast, whence the trailers are carried by ferry to Miami. Although the road distance from David to the port is 1,250 miles, not all of it paved, the total cost is comparable to air transport (about 5 cents per pound). This method has proven so satisfactory that most of the shipments from David now go by trailer.

The shrimp industry has a considerable impact on the economy of Panama. It provides direct employment to thousands of people in Panama City, and the business generated through purchases made by the industry provides jobs for many others. To a casual observer this can be lost sight of in a large city, but those who follow the economy and the unemployment statistics know that the shrimp fishery is vital to the well being of the city and the country.

Realizing the value of the shrimp industry, the government has offered it various inducements. The operating companies have 25-year concessions and are free from corporation taxes. There are no export taxes. As in other fields, foreigners may operate in the shrimp fishery by setting up Panamanian corporations and by using vessels built in Panama. There is no restriction against foreigners as plant officials or employees.

Colombia

Shrimp are found along most of Colombia's 500 miles of Pacific coastline. The shrimp industry is concentrated at Buenaventura, which is located about midway between Panama and Ecuador. Buenaventura is also Colombia's principal port for commercial shipping. A very small shrimp fishery is carried on at Tumaco, a port near the southern border.

Beginning with the first trawler in 1943 and fluctuating since, the Buenaventura shrimp fleet consisted of 154 registered vessels plus 31 small unregistered boats in 1970. All craft are of Colombian registry.

In recent years Colombia has developed a boat building capacity at Barranquilla, financed by the Instituto de Fomento Industrial (IFI) to make Colombia self-sufficient in its need for fishing vessels. As of 1970, this agency had financed construction of 89 new shrimp boats for Colombia and, with the Fondo de Promocion y Exportacion, financed 37 boats for export.

Ownership is of two kinds, company and private; the larger and better boats are company owned. The 1971 Pacific shrimp fleet consisted of 154 vessels, about half wood, of which about 125 operated at any one time. A recent survey by FAO and the Colombian Institute for the Development of Renewable Natural Resources (INDERENA) recommended a limit of 125 operating shrimp boats for this fishery. Vessels range from 33 to 82 feet long; new boats are being built in the 65 to 78-foot range and some equipped with freezers.

Nine firms on the Pacific Coast operate shrimp processing and freezing plants; six are in Buenaventura. Recent figures indicate that about 75 percent of the shrimp catch is exported and the rest consumed domestically. Although most exports are to the United States, Japan has recently been bidding for a share. The plants are as follows:

Buenaventura:
Alianza Colombiana de Pesca, Ltda. (ACOPESCA)
Pesqueros Unidos de Colombia, Ltda.
Pesquerias del Pacifico, S.A.
Empresa Colombiana de Pesca, Ltda. (LA POLAR)
Asociacion Pesquera Arlibia, Ltda.
Industria de Pesca sobre el Pacifico (INPESCA)

Tumaco:
Productos del Mar Ltda. (PRODEMAR) Grupo Manccini
Pesquera de Tumaco, Ltda. (PESMACO)

Guapi:
Recursos del Mar Ltda. (REDMAR)

Table 9.—United States imports of shrimp from Colombia, 1961-71.

Year	Volume	Value
	1,000 pounds	*$1,000 U.S.*
1961	1,873	1,237
1962	2,207	1,592
1963	1,870	1,256
1964	1,774	1,343
1965	1,796	1,366
1966	2,212	1,695
1967	2,726	2,031
1968	3,018	2,895
1969	3,703	3,659
1970	4,802	4,643
1971	4,841	4,891

Note: The above figures are almost entirely heads-off, shell-on shrimp. A small proportion in the later years is peeled and deveined.

Most of the catch is white shrimp, called "camaron blanco" or "langostino," and the three species are not separated in the industry. In all fishing areas and seasons, *Penaeus occidentalis* constitutes about 82 percent of the landings. *P. vannamei, P. brevirostris, P. californiensis, Xiphopenaeus riveti,* and *Trachypenaeus byrdi* account for most of the remaining catch. Occasionally, especially in the dry season, these species constitute up to 18 percent of the landings.

The fleet operates along most ot the coast of Colombia south of Cabo Corrientes, about 150 miles south of the border with Panama. Trawling is carried on at 3 to 15 fathoms, mostly less than 8 fathoms.

The fishery operates in four well-defines areas (known for research and statistical purposes as zones). They are separated by stretches of deep water and rocky coast where fishing is not possible. From north to south, the fishing zones are as follows:

Zone I. Zone of Cabo Corrientes. This area extends south from the cape to Punta de Piedra, which is near Buenaventura. This area has numerous excellent nursery grounds, including the estuary of Rio San Juan and Juanchaco. The heaviest fishing is near Puerto Pizarro. The best season is May to December. Most fishing is in

the daytime, because strong winds and a heavy surf make fishing close to shore at night very dangerous. This zone is primarily a feeding area for the shrimp, which are larger than elsewhere in Colombia. Presumably they move in from the south; the area has no extensive lagoons for nursery grounds.

Zone II. Zone of Tortugas and Timpiqui. This important area, from Punta de Soldado to Timpiqui, has the excellent nursery grounds of the rivers Raposo and Cajambre and extensive shallow mud flats. The Bahia de Tortugas is especially good. The grounds are only 2 hours from port, and fishing is good all year. Most fishing is in the daytime, although it is not dangerous to fish at night.

Zone III. Zone of Tumaco. This area extends from Guapi to Ecuador. The best production area is immediately north of Tumaco. With innumerable rivers and estuaries, this region has the best nursery grounds of all. Perhaps for this reason, the shrimp are smaller in the Tumaco area than elsewhere. With many dangerous shallow bars, even dayiight fishing is hazardous, and little fishing is done at night. The area is fished heavily all year. In 1963 it was estimated that 57 percent of the production originated in Zones III and IV.

Zone IV. Zone of North Pacific. This area extends from Cabo Corrientes northward to Panama. The FAO-INDERENA survey found small shrimp grounds in Bahia de Humboldt, Bahias de Cupico y Chirichiri, and Ensenada de Utria. At present the resource is little fished.

All exports to the United States move directly from Buenaventura on the scheduled refrigerated ships of the Flota Mercante Grancolombiana and the Grace Line.

The processing plants operate under licenses which contain no specific time limits and which specify that they should export 90 percent of their production and sell 10 percent domestically. As producers of "minor exports," they are exempt from income and inheritance taxes; import taxes on fixtures, refrigeration machinery, vessels, parts and engines, nets and fishing gear, electrical equipment, and processing machinery; and various harbor taxes. They may also import various necessities that are otherwise prohibited entry. Required bureaucratic procedures involved in importing and in obtaining these exemptions are time-consuming.

There is no export tax as such, but the required method of payment and the artificial rate of foreign exchange result in a de facto tax. All dollar payments for shrimp exports are made through the government bank (Banco de la Republica). The bank pays the packers in pesos at the rate stipulated for all minor or small exports (of which shrimp is one, as opposed to coffee, a major export), which is less than the open market exchange. For example, in April 1966, when the free exchange rate was about pesos 18.00 per $1.00 U.S., the rate for shrimp sales was 15.50 to $1.00. This is equivalent to a tax of nearly U.S. $0.14 on every dollar. This is far more than the direct export taxes in any other country.

Since 1967 Colombia has had a Fisheries Development Project supported by the Special Fund of the United Nations and operated jointly by FAO and INDERENA. Surveys in the shallow waters of the Pacific are almost completed. Additional shrimp surveys are being made in 100-fathom water. Investigations are also in progress in the Atlantic. Basic work has been done in marketing and processing and legal problems. Work on oysters and freshwater shrimp is also included in the project. Training has been given to numerous biologists, who will continue to work after the project closes at the end of 1972.

The nine freezing plants on the Pacific coast also process and sell frozen finfish in the interior of Colombia. The high cost of transportation by truck and air, however, makes fish from the Pacific coast a high-cost protein in the population centers. Freshwater fish are much cheaper. However, the quality of the ocean fish marketed is good and people in the upper income brackets are willing to purchase a certain amount as a variation in diet. One dollar or more per pound is common for snook, snapper, mojarra, sea catfish, and sea bass. The nine plants cited could expand their production for the export market.

Ecuador

The Ecuadorian shrimp fishery is one of the best developed in Latin America and is a consistent high producer; exports average over 5 million pounds. Along the 500 miles of coastline, shrimp fishing is confined to the 100 miles near Esmeraldas in the extreme north and to the Gulf of Guayaquil in the extreme south. Landings are made at Esmeraldas, Playas, Posorja, and Guayaquil; the last is by far the most important.

The 1971 shrimp fleet was estimated at 195 vessels, of which 145 fish out of Guayaquil and 50 out of Manta. About 75 of the boats are wooden, 65 feet or more long. Only two have steel hulls, and are 75 feet long. About 70 percent of the fleet has brine refrigeration. The average trip of the larger vessels is 2 weeks; the smaller boats in Manta and Playas return to port daily.

In 1971 nine plants packed shrimp in the port of Guayaquil:

Empacadora Nacional, C.A. (ENACA), producing 1 million pounds per year from 49 boats, of which 6 are company-owned, 32 under contract, and 11 individually owned.

Industria Pesquera Ecuatoriana, S.A. (IPESA), production capacity 150,000 to 200,000 pounds per month from 40 boats, part company-owned, part privately owned.

Corporation Pesquera Ecuatoriana, S.A. (COPESA), an older plant being rebuilt.

Six plants smaller than any of the above three are:

Conservas Alimenticias Ecuatorianas Cia. Ltda. (CONALEC);
Compania Distribuidora Nacional, S.A., (CODINASA);
Empacadora Alberti of Ecuador, C.A.;
Ecuadorian Seafoods, C.A. (ESCA),
Empacadora Frigorifica de El Oro (FRIGORO); and
Productos Marinos Industrializados "Inca" del Ecuador (PROMAINDE).

The combined annual production of the six small plants is less than the total of the first three.

In Esmeraldas, Mariscos de Esmeraldas Cia., Ltda., and Pesquera del Golfo, C.A., were packing shrimp in 1971.

Ecuador's exports of shrimp to the United States are shown in Table 10. While most exports are heads-off, shell-on, part of the exports in recent years have been IQF and part peeled, deveined, and block frozen.

Table 10.—United States imports of shrimp from Ecuador, 1961-71.

Year	Volume	Value
	1,000 pounds	*$1,000 U.S.*
1961	4,684	2,986
1962	5,121	4,082
1963	5,631	4,374
1964	5,759	4,265
1965	5,667	4,428
1966	5,239	4,507
1967	5,986	5,359
1968	6,289	5,916
1969	8,901	9,165
1970	5,992	5,735
1971	5,332	6,054

In Ecuador, the name "camaron" is applied generally to all shrimp. In the packing plants, the large shrimp of any species are called "langostinos," and the sea bobs and small specimens of the white shrimp are called "camarones." Almost all the "langostinos" are the white shrimp of three species, also called "blancos." Of these, *Penaeus occidentalis* accounts for 60 percent of the production. Most of the rest are *P. stylirostris*, along with some *P. vannamei*. The whites are taken in 4 to 14 fathoms.

The fishery takes very few pinks, or "rojos," *P. brevirostris*; and browns, or "cafes," *P. californiensis*. The fishery scientists believe that a good resource of pinks exists in deeper waters, but little exploratory fishing has been done. The commercial fishery is strictly in shallow water, close to shore, and as yet the fishermen feel no need to fish offshore. The research vessel of the National Fisheries Institute, while making other studies, had excellent incidental catches of royal red shrimp on an offshore shelf 400 to 500 meters deep.

The small sea bobs are a very important part of the fishery. Two species dominate the shallow-water fisheries at Playas and Esmeraldas: the "pomada," *Protrachypene precipua*, and the "titi," *Xiphopenaeus riveti*. Ecuadorian scientists recognize three species of the striped "tigres" or "zebras": *Trachypenaeus byrdi*, *T. faoe*, and *T. similus pacificus*. The "tigres" spend part of their life histories in the lagoons and estuaries like the whites, whereas the "pomadas" and "titis" do not enter estuarine waters.

The trawlers catch some spiny lobsters incidental to shrimp. They bring in the tails, which are frozen for export. The tails are wrapped individually in polyethylene and packed in cartons. The shrimp plants, and an additional plant that deals only in lobsters, buy whole live lobsters from other fishermen. The tails are frozen raw. The heads are cooked and then frozen for export (to yield picked lobster meat). Eventually, when adequate and sanitary facilities for this work are constructed, it is expected that this work will be done locally.

Almost all the shrimp and lobsters are shipped by refrigerated cargo ship direct to New York. One or two plants ship some by air, via A.P.A., to Miami. The shipping rates are a little over 5 cents per pound by ship and 6 cents by air.

There is no direct export tax on shrimp. However, the exporters are required by the Central Bank to exchange their dollars for sucres at an artificial rate which is lower than the free market and results in a de facto tax. Packers and fishermen pay a variety of small port and local taxes and fees.

Peru

Peru is at the extreme southern edge of the range of the warm-water species of shrimp, and consequently has but a small fishery. Most of Peru's very long coastline is bathed by the cold waters of the Humboldt Current. Although this nutrient-rich body of water supports the world's largest fishery—for the Peruvian anchovy—it is too cold for the penaeid shrimp, which support the Hemisphere's shrimp industry.

The Humboldt Current moves offshore where it meets tropical waters, near Cabo Blanco. Just north of Cabo Blanco are the fishing towns of Puerto Mancora and Caleta Cruz. The entire shrimp fishery is centered in the 30-mile-long area from Caleta Cruz to the border with Ecuador. The trawling grounds are actually an extension of the Ecuadorian grounds of the Golfo de Guayaquil. The only Peruvian nursery areas are the estuaries around Puerto Pizarro, and these are not particularly extensive.

About 80 percent of the production is exported to the United States. Hence, Table 11, which presents official U.S. import figures, gives a good idea of the size of the industry. Weights are mostly heads-off, shell-on, which is the principal type of product.

Table 11.—United States imports of shrimp from Peru, 1961-71.

Year	Volume	Value
	1,000 pounds	*$1,000 U.S.*
1961	358	277
1962	387	335
1963	367	312
1964	308	240
1965	446	419
1966	539	514
1967	254	243
1968	269	292
1969	698	686
1970	309	307
1971	370	371

As of late 1971, the industry consisted of two freezing plants and 25 boats. All boats are based at the open-sea port of Caleta Cruz. Nineteen are small 30- to 40-footers, and six are modern 60-footers. The small boats use single otter trawls. The large vessels, which are converted anchovy and tuna boats, use the double-rigged Gulf of Mexico style shrimp trawls. All are refrigerated with ice.

One small freezing plant (Promarsa) is located in Caleta Cruz. Twelve small trawlers fish for this plant. The other plant (Conulsa), an affiliate of a United States company whose principal operation in Peru is fish meal, is located in Mancora. Its vessels deliver in Caleta Cruz, and their catches are shipped to Mancora by truck.

All three species of white shrimp are caught in the Peruvian fishery. Neither fishermen nor processors distinguish them; all are called "blancos." Probably *P. occidentalis, Penaeus stylirostris, and P. vannamei* are about equally distributed in the catches. Only the largest sizes are used. About 85 percent of the pack is under 15 to the pound (heads-off), and many are under 10. Fishing is carried on out to 15 fathoms, but apparently the shrimp are most

abundant close to shore in 3 to 6 fathoms.

Under the 1970 reorganization of Peru's fisheries, an agency called Empresa Publica de Servicios Pesqueros (EPSEP) was created to develop the food fisheries. Although, as noted above, Peru's shrimp potential is limited, some development work can be expected as part of the nation's overall goal of increasing its food fish and shellfish production.

THE SHRIMP FISHERY OF THE CARIBBEAN SEA

General

The shrimp export fishery of the Caribbean Sea developed much later than on the Pacific Coast. Cuba began exporting in a small way in 1953, but the fishery never became important. Venezuelan exports began in 1957 but were of no real importance until 1961. Export fisheries began in both Honduras and Nicaragua in 1958.

Unlike the nearly continuous shrimp resource of the Pacific Coast, Caribbean shrimp occur in significant quantities only in restricted areas. Only three areas appear to have the environment essential for large populations of penaeid shrimp, i.e., extensive brackish water lagoons as nursery areas for the juvenile shrimp, and open-sea areas with a muddy bottom where the adult shrimp feed and spawn. A relatively level muddy bottom is also necessary for trawling operations.

One of the three areas is in the extreme western Caribbean, from the northern tip of the Yucatan Peninsula at Cabo Catoche southward toward Isla de Cozumel. This extremely limited area is fished by Mexican trawlers based in Ciudad del Carmen and Campeche, by United States vessels based in Florida, and by Cuban boats. The limited fishery is of recent origin. No catch statistics are available, and catches made in this small fishery are not included in any of the production figures presented in this report.

The second area encompasses the extreme eastern part of mainland Honduras, the offshore islands of Honduras, and the coast and islands of Nicaragua. This area is fished by vessels based in Honduras and Nicaragua, and by United States trawlers based in Florida. The United States vessels, some of which pick up their crews at Honduran and Nicaraguan ports, deliver their catches to their home ports in Florida. Hence, their production is not included in any of the statistics presented in this report. As many as 50 or more U.S. vessels may be in the area at any one time. These vessels transfer their catches to homebound boats so they can remain at sea and continue fishing for long periods.

The third and most productive area is in western Venezuela, in Lake Maracaibo and the adjacent Gulf of Venezuela. An enormous fleet of canoes fishes for juvenile shrimp in the lake, and a locally based fleet of trawlers fishes adult shrimp in the Gulf.

The Caribbean shrimp fisheries are based almost entirely on four species of large penaeid shrimp: the white, *Penaeus schmitti*; the pink, *P. duorarum;* the spotted pink, *P. brasiliensis;* and the brown, *P. aztecus.* These occur in differing proportions, depending on area, depth, and season.

Honduras

The Honduran shrimp fishery began in 1958 when United States operators brought in trawlers and established freezing plants. Exports that year were 836,000 pounds, a figure not equalled again until 1963. Ever since its inception the fishery has been unstable, starting and failing in response to a variety of changing conditions.

The Caribbean coast of Honduras runs east and west for about 365 miles. Lying 10 to 30 miles offshore, near the middle of the coastline, are the Bay Islands, consisting of three major islands and numerous small keys. Strung out for many miles east and northeast of the eastern part of the coast are dozens of small uninhabited keys and reefs.

Shrimp are found in quantity only along the 100-mile stretch between Punta Patuca and Nicaragua, and around the keys and reefs offshore. This is the area with suitable trawling bottom and favorable shrimp feeding grounds, and it is adjacent to a series of large lagoons that serve as nursery areas. The 265 miles to the west of Punta Patuca, as well as the Bay Islands, are largely without shrimp. The water is deep, the bottom rough, and the lagoons apparently produce few shrimps.

The physical problem faced by those attempting to establish a shrimp fishery is that the part of Honduras that is near the shrimp grounds is both uninhabited and inaccessible. All the harbor and service facilities, supplies, and sources of labor are to be found in the towns far to the west, on both the mainland and the Bay Islands. Within reasonable reach of the shrimp grounds there are no towns, harbors, roads, railways, or airfields (except the air strips that the shrimp producers build for themselves). The choice lies between establishing plants in towns far away from the fishing grounds or in remote and primitive spots lacking all service facilities and amenities. Both approaches have been tried. In either case, costs of operations have been high, which alone has been enough to keep the industry from expanding to the extent that the available resources warrant.

Another deterrent to greater development has been the constantly changing official attitude toward the participation of foreign investment, vessels, and personnel in the shrimp industry. For example, the boom of 1958 was ended abruptly by the enactment of the Fisheries Law of 1959, which virtually barred foreign participation. It required 51 percent Honduran capital, which was not forthcoming in view of the otherwise risky nature of the business. Subsequently, the Minister of Natural Resources was given authority to grant temporary permits to foreigners.

Since 1959, operations have been partly by Honduran corporations and partly by United States enterprises working under temporary permits. Some permits have called for delivering the catches to shore plants; others allow the transfer of catches to carrier vessels, under supervision, and upon payment of the export taxes. Enforcement of regulations, supervision of plant operations, and collection of statistics are all difficult because the fishery is equally inaccessible to government officials and plant owners.

Two plants pack shrimp on the mainland Caribbean coast of Honduras.

The older of these, Alimentos Marinos Hondurenos, is located at Barra Caratasca and is a joint United States-Honduran operation. It is a small plant, fully self-sufficient, and supplied by seven boats. The second is basically a meat packing operation, handling some shrimp in season, at Puerto Castilla.

On Roatan Island, the largest of the Bay Islands of Honduras, Mariscos de Honduras has built up a substantial shrimp operation in the town of Oak Ridge. Principal U.S. interest is International Oceanographic Corporation of New York. The plant produces about 1 million pounds of headless shrimp a year with 20 modern trawlers.

Guanaja Island, the second largest of the Bay Islands, has two shrimp plants. Caribbean Products (75 percent owned by Alberti Foods of Chicago) packs both headless green, peeled, and deveined, and IQF shrimp. Annual volume is about 750,000 pounds of shrimp, plus between 60,000 and 100,000 pounds of lobster tails. A fleet of 35 boats supplies this plant. An older and larger plant on the same island is that of Industria Pesquera Hondurena, Spanish owned and managed. This plant is reported to have a capacity of 2 million pounds of shrimp production per year, and is supplied by 36 boats, of which 15 are company owned.

Practically all of the Honduran shrimp production is exported to the United States. Hence, Table 12, which gives official United States import figures, summarizes the growth and size of the industry based in Honduras.

Table 12.—United States imports of shrimp from Honduras, 1961-71.

Year	Volume	Value
	1,000 pounds	*$1,000 U.S.*
1961	227	150
1962	379	259
1963	835	472
1964	698	493
1965	1,632	1,069
1966	2,107	1,670
1967	1,922	1,751
1968	2,981	2,819
1969	3,925	3,983
1970	2,415	2,346
1971	3,942	3,967

The Honduran shrimp fishery is based on two species: the white shrimp, *Penaeus schmitti*, and the pink shrimp, *P. duorarum*. The catches consist of about equal amounts of the two species, with most of them in the 26/30 size range (heads-off weight).

The following information is a summary of the findings of a FAO biologist who observed the fishery in 1959, 1960, and 1961:

White Shrimp. The fishery grounds are from Punta Patuca to Nicaragua. The whites are taken in less than 20 fathoms. In 1959, two-thirds were taken in depths of 11 to 20 fathoms and one-third in less than 5 fathoms. In 1960, 90 percent was taken in less than 10 fathoms, the rest in 16 to 20. The whites are most abundant from August to mid-November. Although the sizes vary from year to year and within a season, they run mostly 21/40, with none under 15.

Pink Shrimp. The fishing grounds extend from longitude 84° W. (several miles east of Punta Patuca) to the Nicaraguan border. Practically all pinks are taken in 16 to 25 fathoms. (As of 1961, little exploration had been conducted beyond 25 fathoms, and the fishery around the offshore keys had not developed.) Pink shrimp become abundant in late September or October, then gradually decrease after November until March or April, when fishing for them ends. The sizes run mostly 21/40, varying from month to month.

Brown Shrimp. Very few browns are taken. They are mostly 26/30 to the pound.

Since 1959, the export tax has been 50 cents per metric ton, plus 10 percent ad valorem, established on a basic price of 40 cents per pound. In total, this amounts to a little over 4 cents a pound.

Nicaragua

Nicaragua has a 285-mile Caribbean coastline. The only port where shrimp are landed is Bluefields, 200 miles south of Honduras and 85 miles north of Costa Rica. The eastern part of the country, referred to as Costa Atlantica, had long been isolated from the rest of the country because of a lack of communication across the jungle and wilderness that lie between the coast and the capital at Managua. Several years ago, regular airline service was provided that now connects the two parts of the country. Furthermore, an all-weather road has been built eastward from the capital to the head of navigation on the Rio Escondido, which empties into the Mar de Las Antillas (Caribbean) at Bluefields.

The Caribbean coast is blessed with an excellent series of large brackish water lagoons and estuaries that provide outstanding nursery areas for young shrimp. Annual rainfall of some 200 inches assures adequate fresh water. Good shrimp feeding grounds, with excellent trawling bottom, are found along almost the entire coast from the mainland beach out to beyond the many offshore keys and islands.

At El Bluff, which is a port of entry at the entrance to Bahia Bluefield, Booth Fisheries de Nicaragua, S.A., took over a French-built shrimp plant that failed in 1962. Using U.S. capital and management, Booth rebuilt the plant into one of the most modern in Central America. The company is partly owned by the government corporation known as the National Institute of Development (INFONAC). The plant produces about 3.5 million pounds annually.

Later, another plant, Pescanica, S.A., started operations on Schooner Key, an island in the bay. This plant has a potential production capacity of 1.5 million pounds and is owned partly by Atalanta Trading Company of New York.

Still another plant, PROMARBLU, recently opened up on Corn Island, a few miles off the coast in the Caribbean. This plant has a production capacity of about 1 million pounds annually and operates 20 modern steel trawlers.

Although starting operations without any company-owned boats, Booth operated 12 steel trawlers in 1971 and Pescanica had 10 steel trawlers. As the fishery is seasonal, the size of the total fleet varies as U.S. and Mexican vessels come to the area to fish for the two plants. During the peak of the fishing season, Booth may have over 40 boats fishing and Pescanica over 20.

Recent government restrictions limit shrimp drying to sea bobs. Two small companies dry shrimps for export, Kai Yun Chan on Laguna de Perlas, a few miles north of Bluefields, and Ernesto Hooker on Rio Huahua, near Puerto Cabezas on the North Coast. They buy

the catches of canoe fishermen who use cast nets in the nearby lagoons and estuaries.

Most of Nicaragua's shrimp production is exported to the United States (Table 5).

Of the four species taken by the freezing plants, the two varieties of pink shrimps are by far the most important. The pink, *Penaeus duorarum*, and the spotted pink, *P. brasiliensis*, are taken together in about equal proportions. They are not separated in the plants. The most numerous size range is 21/25 (heads-off, shells-on).

Both of the pinks are offshore species, occurring around the keys and islands. They are usually fished at depths of about 25 fathoms.

The pinks usually appear in October and are caught into the following May. The best grounds lie within the triangle formed roughly by Punta de Perlas (Pearl Point), Islas del Maiz (Corn Islands), and Punta del Mono (Monkey Point, also called Punta Mico). The points of this triangle are (from El Bluff): Pearl Point, 30 miles north; Monkey Point 30 miles south; and the Corn Islands, 50 miles northeast. The slowest season for all species is mid-May through July, when most fishing is south of El Bluff.

The white shrimp, *Penaeus schmitti*, is important seasonally. The adult whites leave the lagoons for the ocean when the heavy rains begin in June. They are fished August through December. The fishing grounds are separate from those for the pinks, and extend from Cabo Gracias a Dios past Puerto Cabezas to Prinzapolea, about 130 miles. From Prinzapolea to El Bluff is a run of 95 miles. The whites, fished only in daytime, live in very shallow water. Sometimes the trawlers operate just outside the breaker line in 1.5 to 2 fathoms. Occasionally the whites are so close to the beach and in such great quantities that the local residents can catch them in sacks, screens, and buckets. In recent years increasing quantities of brown shrimp, *P. aztecus*, have been taken in the same area and season as the whites. They are caught a little farther from shore and are fished at night.

All frozen shrimp are shipped to the United States by refrigerated ships, mostly in the standard 5-pound cartons and master cartons. As of 1971, about 50 percent exports were IQF.

The export tax on all shrimp, regardless of species or size, is 3 cents a pound.

Venezuela

Venezuela's modern shrimp fishery began about 1959, in Maracaibo. Large-scale exports began in 1961. After a preliminary shakedown, the industry underwent a meteoric expansion, on a scale never seen elsewhere. With a smaller fishing area than most countries, the Venezuelan fishery by 1965 was producing more shrimp than any other fishery south of Mexico. The explanation of the enormous catches (16 million pounds in 1965) lies in the tremendous productivity of Lake Maracaibo, probably the greatest nursery area for white shrimp in the Americas.

Venezuela has a 1,750-mile coastline, including gulfs and islands; over three-fourths of the coast faces the Caribbean Sea and the remainder the Atlantic Ocean. As noted below, shrimp have been caught in commercial quantities only in the extreme west, and the fishery is essentially confined to the Gulf of Venezuela and Lake Maracaibo, close to the Colombian border.

Most of Venezuela's shrimp production is exported to the United States; Table 13 shows the growth of the industry in the last 10 years:

Table 13.—United States imports of shrimp from Venezuela, 1961-71.

Year	Volume	Value
	1,000 pounds	*$1,000 U.S.*
1961	2,469	1,115
1962	6,341	4,067
1963	5,790	3,344
1964	7,904	4,457
1965	12,719	7,976
1966	2,881	2,432
1967	4,773	4,067
1968	5,403	4,756
1969	5,851	5,804
1970	11,563	11,288
1971	10,083	11,921

As can be seen by Table 13, Venezuela's shrimp industry declined sharply in 1966. While many factors were blamed for this, experts believe that the poor fishing was due to some cyclic change in abundance, such as has occurred in other shrimp fisheries in the past. For the next 3 years, production was less than half that of 1966 and the industry was confronted with problems of finances and quality. These were largely overcome, however, and in 1970 production increased again to over 11 million pounds. The situation continued good through 1971.

Lake Maracaibo and its distributary system of waterways constitute an almost perfect environment for the production of shrimp. They contain excellent feeding, spawning, and nursery areas, apparently in the right proportions. Every necessary degree of salinity is present, along with water temperatures conducive to year-round spawning and growth. Furthermore, the harvest of shrimps is made possible by the existence of suitable fishing grounds for several types of gear. If a model shrimp area were to be designed, it could not improve upon the Maracaibo complex as it exists today.

The heart of the area is Lake Maracaibo itself. The lake covers about 5,500 square miles and is the largest lake in South America. Its watershed totals 35,000 square miles, much of it mountainous and with heavy rainfall. Most of the lake is shallow, but a maximum depth of 115 feet is reached in the southeast portion. The waters of the lake are a mixture of fresh water from the outflow of many rivers and sea water entering from the mouth of the lake. Until 1958 the salt content had fluctuated around one part of sea water to 25 parts of fresh water, but recently salinity has risen to more than double the former amount. This has been due to the construction of a deep-water channel to permit the passage of oil tankers to and from the petroleum installations that ring the lake. A counter-clockwise circulation, driven by the wind, brings sea water to the surface in the middle of the lake and provides for a uniform surface salinity throughout. The shore areas of the lake, particularly the northwestern portions, are splendid nursery areas for white shrimp. Temperatures in the lake range from 28° to 31°C.

The lake drains into the small, shallow Bahia de Tablazo through the Estrecho de Maracaibo, on the west shore of which lies the city of Maracaibo. The bay is a typical transition zone, abounding in mangrove habitat, with hydrographic conditions changing seasonally.

Both the bay and the strait are excellent nursery areas for juvenile white shrimp.

The bay empties into the Gulf of Venezuela through a series of channels, one of which has been dredged for the passage of tankers. The gulf covers an area of about 6,500 square miles. It is protected from the open waters of the Caribbean by the Peninsula de Paraguana on the east and the Peninsula de la Guajira on the west. (The outer extremity of the latter peninsula is in Colombia). The gulf is subdivided into two parts, the gulf proper on the east, and the Ensenada de Calabozo in the west, lying south of the Peninsula de la Guajira. A shallow ridge, running north and south, divides the two parts. Calabozo has a maximum depth of 15 fathoms, whereas the outer gulf is as deep as 44 fathoms at its mouth. As could be expected from the depth pattern, white shrimp are found in Calabozo, and browns and pinks are taken in the open gulf. Surface water temperatures vary seasonally from 25° to 28°C.

Completing the environmental complex is a small protected gulf, the Golfete de Coro, which is an identation of the main gulf on the east, completely protected by the Peninsula de Paraguana. This shallow bay, along with the nearby shores of the gulf itself, is the principal nursery area for juvenile brown and pink shrimp.

Nine species of shrimp are found in the Maracaibo area. Seven are penaeid species, of which four are important commercially. The two caridean species are of minor importance. In general terminology, the local fishermen refer to all large shrimp, regardless of species, as "langostinos." The smaller shrimp are called "camarones," and the smallest are "camaroncitos."

By far the most important species is the white shrimp, *Penaeus schmitti.* Known as "langostino blanco" or "camaron blanco," this species may account for as much as three-fourths of the total production. Apparently the whites spawn throughout the year on their principal feeding grounds in the Ensenada de Calabozo. The postlarvae apparently migrate to the nursery areas of the Bahia de Tablazo and the adjacent shores of the open gulf, the strait, and the lake itself. As subadults they return to Calabozo where they later enter the fishery as the predominant species. As adult shrimp, the whites constitute about 50 percent of the total catch made in the Gulf of Venezuela. In the fishery in Lake Maracaibo, the juvenile whites account for 90 percent or more of the catch, depending on place and season.

Three other species of penaeid shrimp inhabit the eastern or open, deep water part of the Gulf of Venezuela. Most important of these is the pink shrimp, *P. duorarum* known as "camaron rosado." This species constitutes 50 to 75 percent of the catch made in the outer part of the gulf. The spotted pink shrimp, *P. brasiliensis,* is found mostly just outside the gulf proper, north of Cabo San Ramon; because little fishing has been done in this area, the true abundance of this shrimp is not known. This species is known locally as "camaron rosado con mancha." The third species is the brown shrimp, *P. aztecus,* known locally by the specific name of "camaron marron." The brown shrimp contributes about 20 percent of the catches made in the outer gulf. The fishermen group all three species together and give them the general name of "camaron marron." (Scientists also group them for convenience and call them grooved shrimp, as distinct from the whites.) Some of the plants pack them all indiscriminately as browns; some separate them as pinks or browns, depending on color (which is variable). The nursery grounds for all three species are in the Golfete de Coro, where a small fishery exists, and along the nearby shores of the main gulf. At times, these species appear in the catches in Lake Maracaibo in appreciable quantities, so this area is probably a fairly important nursery area for them also.

Because of the confusion of local nomenclature, and because of the difficulty of accurate identification of the younger stages, which are quite similar, it is difficult to say precisely what proportion of the catch in the lake is composed of the various species of grooved shrimp. However, it has been estimated that *P. aztecus* accounts for nearly 10 percent of the total lake catch.

Completing the list of penaeid shrimps are the sea bobs, *Xiphopenaeus kroyeri* and *Trachypenaeus similis,* and a rock shrimp which has been identified tentatively as *Sicyonia stimpsoni.* The latter two are of no commercial importance. *X. kroyeri* is taken in small quantities in the Calabozo fishery. Known as the "siete barbas," it is also called "camaron blanco," and the larger individuals are marketed along with the true whites. It does not appear to be very abundant.

The two caridean shrimp are found in the lake, particularly in the more southerly parts that are influenced by the many rivers. *Macrobrachium acanthurus,* or "brazo largo," is of little commercial importance. However, *M. amazonicum,* or "camaroncito del rio," is often caught in considerable quantities. It sometimes constitutes as much as 15 percent of the catches in the lake. Also known as "camaroncito blanco," it is marketed along with the juvenile whites. In fact, the lake fishermen remain convinced that it is the same species. Because they often catch *M. amazonicum* in the egg-bearing stage, they believe that the spawning grounds of the white shrimp are in the southern part of the lake. The government biologists have tried in vain to explain that the true white shrimp (like all penaeid species) is a free spawner and does not carry its eggs attached to its swimmerets.

The Maracaibo shrimp fishery really consists of several types of fisheries. Two different trawl fleets operate in the Gulf of Venezuela. Three kinds of canoe fisheries are active along the shores of the gulf, in the Golfete de Coro, Bahia de Tablazo, the Estrecho de Maracaibo, and particularly in Lake Maracaibo. It has been estimated that the trawl fisheries of the gulf account for two-thirds of the total production, and the canoe fisheries the rest.

The larger of the two trawl fleets, and the first to be established, is based at Punto Fijo on the Peninsula de Paraguana. In 1969 this fleet consisted of 116 boats. While many of these are the Italian boats that entered the shrimp fishery a number of years ago, newer Florida-style vessels are also included in this fleet. All use the double rig.

The second trawl fleet, 18 vessels in 1969, is based at Maracaibo. All are Florida-style boats ranging from 62 to 65 feet in length, with some larger. The rest of the total shrimp fleet of 159 vessels consists of a handful of boats at each of the ports of Cumana, Puerto La Cruz, Carupano, Guiria, and Punta Piedras.

About 3,200 canoe fishermen fished shrimp in the Maracaibo area, using 636 small boats. During periods of exceptionally good shrimping, other fishermen join them, so that at times over 4,000 men are taking shrimp.

After the various ups and downs experienced by Venezuela's shrimp industry in earlier years, the number of shrimp processing plants has settled down to 10. Three of these in the Maracaibo area are Lacustre de Pesca, Congeladora de Venezuela, and FIAVESA, all modern and well run. In Punto Fijo the two principal plants are FIVECA, owned by a U.S. firm, and AVENCASA, whose freezing capacity is 50,000 pounds per day.

Shipments are made to the United States by both air and sea. Two local airlines offer rates of 4 cents per pound gross, while several steamship lines offer service with better refrigerated temperature control at 4.5 cents per pound net.

Venezuela has no export tax on shrimp; however, plant owners must pay import duties on such items as equipment and machinery, most of which comes from the United States.

Colombia

Colombia's shrimp fishery along its 630-mile Caribbean coastline is relatively recent. In 1966 its shrimp fishery was described as of only local interest, but with considerable potential. At least some of this potential is now being realized.

In Barranquilla, 15 miles up the Magdalena River, three companies, PESCAMAR, COPESCOL, and Pesquera del Atlantico, are in the shrimp business. The first was undergoing a rebuilding program in late 1971 involving all new equipment, including freezers and ice plant; it operates two 72-foot boats in addition to other smaller ones. The second company, COPESCOL, had a small shore plant packing the shrimp from the five vessels of PESCAMAR. Production at Barranquilla should increase when the third plant, Pesquera del Atlantico, has completed its modernization.

Also at Barranquilla is the shipyard Astilleros Magdalena, Ltd., an impressive establishment building 72-foot steel shrimp boats both for the domestic fleet and for export. In late 1971 it was completing an order for 10 of these vessels for Nicaragua.

Further west in Cartagena, the shrimp processing firm of Vikingos de Colombia dominates the scene. This is a good, clean, and fairly modern plant with daily freezing capacity of 70,000 pounds. Most of its production is headless unpeeled shrimp, with some peeled and deveined for block freezing. All production goes to a firm in Miami.

The Cartagena fleet fishing for Vikingos consists of 53 shrimp boats, of which 22 are U.S. flag, mostly from Tampa. Future plans call for increasing this fleet to 72 boats, including 10 new boats to be built in the shipyard at Barranquilla.

A Colombia license costs 50 pesos (about US $2.00) per gross ton annually, and is issued only when there is a local plant contact.

The Cartagena fleet fishes year round, from the Venezuelan border to Panama in 20 to 40 fathoms. The best months are October to January. Average catch of a 14- to 15-day trip is 3,000 to 5,000 pounds, heads-off.

Other Countries

As noted in Section III-A, the shrimp fisheries of the Caribbean area are concentrated in a few localities, particularly off Honduras, Nicaragua, and a small part of Venezuela. Trawlers based in the United States and Mexico fish off Mexico, and United States vessels fish off Honduras and Nicaragua. Otherwise, the shrimp fisheries are sporadic and are largely small-scale operations for local markets. The primary reason for the lack of fishing is that no great quantities of shrimp are to be caught, largely because the combination of favorable nursery areas, feeding grounds, and a sea bottom suitable for trawling is missing. Throughout the entire Caribbean, with the exception of Honduras, Nicaragua, and Venezuela, the spiny lobster fishery is far more important than shrimp fishing. Some of the mainland countries (including Nicaragua), and nearly all of the islands, have flourishing lobster fisheries based on exports to the United States and Europe.

The waters around the Bahamas support a small-scale shrimp fishery, mostly to supply the local market and the tourist hotels. Occasionally, small quantities are shipped to the United States.

Cuba was one of the first countries to develop a shrimp fishery based on exports to the United States. The industry began in 1953, reached its peak in 1957, and ceased abruptly in 1960 when the United States suspended all trade. Revival began again in 1969, when the first of 90 shrimp boats ordered from Spain entered the fishery. Since then, all of these vessels have operated in the Gulf of Mexico, the Caribbean, and off northern South America. Most of the production of both shrimp and lobsters is exported to Europe, Canada, and Japan.

Jamaica has a small-scale fishery for shrimp to supply the domestic market. Most of the shrimp are taken incidentally in the fishery for finfish, but they find a ready market. Small quantities are exported to the United States from time to time, along with lobster. Recorded United States imports of shrimp from Jamaica are 6,000 pounds in 1967, 30,000 pounds in 1968, and 3,000 pounds in 1971. Normally, Jamaica imports frozen shrimp from the United States to supplement its own small catches.

Haiti and the Dominican Republic have only small-scale local fisheries for the domestic market. However, Haiti manages to export some shrimp, as indicated by United States import figures of 1,000 pounds in 1967 and 3,000 pounds in 1971. In 1969 imports rose briefly to 54,000 pounds.

Puerto Rico has a small-scale shrimp fishery that cannot supply the local demand. Hence, considerable quantities of frozen shrimp are imported.

Throughout the Lesser Antilles are numerous small shrimp fisheries, but none of any importance. These mostly supply local markets, but occasionally some shrimp are exported.

The maze of keys and islands lying off the coast of British Honduras is the site of a very important spiny lobster fishery. Although the area appears suitable for shrimp, considerable exploratory fishing has failed to locate any substantial resources. Small quantities are taken off the southern coast, near the border with Guatemala. From time to time, small amounts are shipped to the United States (Table 14).

Table 14.—United States imports of shrimp from British Honduras, 1961-71.

Year	Volume	Value
	1,000 pounds	*$1,000 U.S.*
1961	1	n.a.
1962	20	n.a.
1963	7	n.a.
1964	5	n.a.
1965	n.a.	n.a.
1966	39	40
1967	385	347
1968	506	439
1969	297	276
1970	18	28
1971	34	45

The Caribbean coast of Costa Rica is noted for its valuable, if erratic, spiny lobster fishery; however, there is no shrimp fishing.

The environment appears to be satisfactory for shrimp, but there has been little or no exploration. Nicaraguan trawlers that have fished their coast almost as far south as the Costa Rican border report shrimp in some abundance. The area near the border with Panama also appears to hold some promise. No shrimp fishing has been carried on along the Caribbean coast of Panama. Exploratory work has not disclosed adequate shrimp resources to interest anyone. Furthermore, the continually stormy weather has tended to discourage operations. The Panamanian shrimpers are content to fish in the storm-free waters of the Pacific, where a constant supply of shrimp is assured. It is suspected by some that additional exploratory fishing among the bays and islands around Bocas del Toro, near the Costa Rican border, would disclose the existence of a commercially fishable resource.

THE SHRIMP FISHERY OF THE ATLANTIC COAST OF NORTHEASTERN SOUTH AMERICA

General

The waters off northeastern South America have been called the greatest shrimping grounds in the Western Hemisphere. The description is not exaggerated. First exploited on a large scale in 1959, they supplied the U.S. market with almost 22 million pounds of shrimp in 1971.

This shrimping area lies off the coast of South America between the mouths of the Orinoco and Amazon Rivers. Shrimp bases have been established (in approximate chronological order) in Surinam, Guyana, French Guiana, Barbados, and Trinidad and Tobago. Fleets from all these places mingle on the fishing grounds, which by mid-1965 had been developed to encompass the areas described.

In general, fishing is carried on 50 to over 100 miles from shore, in depths of 15 to 34 fathoms. The sea bottom is characterized by a gently sloping shelf from shore out to 32 to 34 fathoms. At this depth, the shelf drops off abruptly. This dropoff is about 50 miles from the coast off Guyana and extends farther offshore until off the mouth of the Amazon it is over 100 miles from land. The best catches are made along the dropoff, and nearly all fishing is concentrated at that depth.

Fishermen have given names to each of the five fairly well-defined fishing areas, as follows:

a. *The West Grounds:* these lie off the coast of Guyana. They were the first to be harvested and are still popular.

b. *The Middle Grounds:* these are off the coast of Surinam (54°W. to 56°30′W.)

c. *The East Grounds:* these are off the coast of French Guiana, west of Cayenne (54°30′W. to 54°W.)

d. *The Rock:* these grounds are near two small islands offshore from Cayenne, between 52°W. and 52°15′W. This is a favorite area for boats to transfer their catches to home-bound vessels.

e. *The Gullies:* these grounds, in the Amazon area, extend eastward from Cabo Orange (westernmost point on the Brazilian coast) to 47°30′W. At Cabo Orange there is some fishing as close to shore as 30 miles, but the dropoff veers away from land to over 100 miles at the eastern part of the fishing area. The usual limit of fishing is at 48°W., 1°N. The bottom is featured by many mud hills and gullies, where the best fishing is encountered.

All of the fishing grounds are characterized by heavy seas and strong currents. The currents flow west, and as most of the fishing is east of the respective home ports, the vessels buck into the current outbound (and are hard put to exceed 6 knots) but can ride the current home when laden. Initially typical Florida-style 62- to 63-foot vessels were used in the fishery, but they were not suited for operation in the heavy seas and currents. Many of them did not last long, and neither did their crews. Replacement with 72- to 75-footers, and later up to 86-footers, heavily powered, proved satisfactory, and the whole complexion of the fleet changed. The larger vessels can fish every day of the year.

The most abundant shrimp, and the basis of the fishery, is the spotted pink shrimp, *Penaeus brasiliensis.* Also occurring is the somewhat similar pink shrimp, *P. duorarum,* which is not distinguished by the fishermen (and often not by the scientists); consequently, it is not possible to estimate the proportion of this species in the catch. The brown shrimp, *P. aztecus,* is caught in some quantities. The white shrimp, *P. schmitti,* occurs in shallow waters. The boats seldom fish in the shallows, where shrimp are scarce and trash fish are plentiful. (Throughout this section, the word shrimp without any qualifying adjective refers to the spotted pink shrimp.)

The sea bob, *Xiphopenaeus kroyeri,* is extremely abundant, particularly around river mouths. It is the object of local fisheries, but it is an important reserve resource of enormous size, if and when it becomes profitable to fish for it. Two very small species, *Palaemon schmitti* and *Hyppolysmata oplothoroides,* are also important in the local fisheries, particularly in Guyana. The National Marine Fisheries Service's research vessel *Oregon* discovered fairly good quantities of various species of deep-water shrimp, but these are not expected to form the basis for a fishery as they are scattered and not readily accessible.

The several enterprises established in the various countries to harvest the shrimp of the Guiana-Amazon grounds all follow the same general operating pattern. Each consists essentially of a fleet of far-ranging trawlers; a shore

base which includes a freezing plant, shops, parts depot, etc.; and a distribution system for the finished product in the United States. They all require, within reasonable propinquity to the fishing grounds, a source of good labor and vessel crews, boatyard facilities, ice-making plants, fuel supplies and groceries, hospitals, electric power, living quarters for supervisory personnel and boat captains, air service for flying in replacements on rotation, shipping facilities for the frozen shrimp, and above all, government permission to operate under terms that will permit them to make a profit and at the same time provide a boost to the local economy.

The problem of unauthorized transfers of catches at sea, and sale or barter by the skippers, is serious in the Guiana fishery, as elsewhere. In self defense, operators have banded together to prevent this practice, hiring undercover agents and offering rewards.

The shrimp fishery of the Guianas is described in the following subsections, country by country. Information given was obtained in late May 1971. Because of the problems created by Brazil's claims to extended jurisdiction, some United States flag vessels withdrew from the area late in 1971. Production figures and fleet sizes are therefore subject to revision, mostly downward.

On May 9, 1972, the United States and Brazil signed an agreement which would remain in effect at least until January 1, 1974. The agreement establishes a shrimp conservation zone off the coast of Brazil within which the activities of shrimp vessels of the two countries will be regulated.

On May 19, 1972, Brazil and Trinidad and Tobago signed an agreement providing for continued fishing by Trinidad and Tobago vessels in the waters adjacent to Brazil during the period May 1, 1972, to November 30, 1973.

Barbados

Barbados is the easternmost island of the West Indies and the closest port in the Antilles to the Guiana shrimp grounds. From 1963 to 1970 it enjoyed a flourishing shrimp industry. Peak production was 2.3 million pounds in 1968 from 32 boats. Commencing in 1969, however, problems of poor maintenance of the shore facilities, demands of labor groups and the Barbados Government, and failure by certain groups to meet commitments led to the shutdown of the industry by the end of 1970. Twenty-six shrimp boats shifted their operating base to Port of Spain, Trinidad, and the few others returned to the United States.

Trinidad and Tobago

Trinidad's principal fishery is shrimp. For political and economic reasons, its capital, Port of Spain, offers a desirable base from which as many as 115 shrimp vessels have fished the grounds off the Guianas and northeast Brazil. In 1970, these vessels, of which 76 were U.S. flag, caught 4.8 million pounds of heads-off shrimp valued at U.S. $5.5 million. International Foods, Ltd. (U.S. interest—15 percent) provides all of the shore facilities for this fleet in two locations. The first and oldest location processes and freezes various food products and has a storage capacity of 2,500 tons. The second, a new installation called "Sea Lots," is modern, large, and complete in every respect, including a number of buildings that fleet operators use for such activities as net and engine repairs. The Government of Trinidad and Tobago built three large piers at this location, and the Texaco Company has installed a fuel tank "farm". However, because of problems created by Brazil's claim to a 200-mile territorial sea, the bulk of the United States shrimp fleet left Trinidad in 1971, reducing the Trinidad-based shrimp fleet to about 20 boats. The Sea Lots plant continued, therefore, to be unused. Future plans call for it to be used when the size of the fleet justifies its opening. Then the old freezer plant, with a total storage capacity of 2,500 tons, will be used for processing and freezing other food and for handling tuna.

About 80 percent of Trinidad's shrimp production is exported to the United States, 10 percent to Japan, 4 percent to other Caribbean countries, and 6 percent consumed locally. Table 15 shows imports to the United States.

Guyana

Of the several countries fishing the Guianas area, Guyana, formerly British Guiana, has by far the greatest production. In 1970 its shrimp production was 11.8 million pounds, heads-off, with a value of US $14.76 million. In addition, Guyana produced 13,000 tons of finfish, consisting of snapper, grouper, croaker, mullet, and sea trout. The small-boat fleet comprises some 1,200 boats, many of them either inboard or outboard powered, and 175 trawlers, of which 171 are offshore shrimp trawlers. Of the offshore vessels, 122 fly the U.S. flag. Chinese seines, Cadell lines (a type of longline), pin seines, and gill nets are used to catch fish on the broad shallow flats that fringe Guyana's 300-mile coast line.

Georgetown has two shrimp plants: Georgetown Seafoods (100 percent United States owned), from which four United States fleet owners operate 83 vessels; and Booker's plant (British owned and operated), from which 88 vessels, 29 of them United States flag, are managed. Georgetown Seafoods can freeze and process 60,000 pounds of shrimp per hour and store 500,000 pounds. The Booker's plant has the capacity of freezing and processing 70,000 pounds per hour and holding 250,000 pounds.

Georgetown also has the Government

Table 15—United States imports of shrimp from Trinidad and Tobago, 1961-71.

Year	Volume	Value
	1,000 pounds	*$1,000 U.S.*
1961	15	10
1962	—	—
1963	—	—
1964	—	—
1965	180	137
1966	1,228	1,233
1967	1,710	1,875
1968	3,076	3,589
1969	2,643	3,112
1970	3,895	4,129
1971	2,434	2,878

Table 16.—United States imports of shrimp from Guyana, 1961-71.

Year	Volume	Value
	1,000 pounds	*$1,000 U.S.*
1961	3,506	2,305
1962	4,129	3,582
1963	5,509	4,668
1964	5,502	4,020
1965	7,972	6,128
1966	8,780	7,306
1967	9,452	6,676
1968	8,349	7,692
1969	8,155	7,533
1970	10,165	11,705
1971	8,981	12,396

Fish Market and Center, serving as a local fish freezing and distribution center. The center has a freezing capacity of 35,000 pounds and holding capacity of 40,000 pounds. Farther along the coast at New Amsterdam is also a Fish Center with a freezing capacity of 17,000 pounds and a holding capacity of 90,000 pounds.

Although Georgetown serves as an important base for the Guianas shrimp fishery, very little shrimp fishing is done off Guyana. The principal grounds are to the east, off Surinam, French Guiana, and northeast Brazil.

As a result of a study carried out by a UNDP/FAO Fisheries Development Project, the Government of Guyana has ordered 10 new shrimp boats, five from a Mexican yard and five from Colombia, at a cost of US $1.25 million. These vessels were expected to be delivered in late 1971 to form the nucleus of what was expected to be a Government-operated fish industry. A second step of the plan, subject to financing being arranged, calls for a $1.5 million shore plant to handle both shrimp and finfish; the fish are to be used both for local consumption and for export to other Caribbean countries.

About 90 percent of Guyana's shrimp production goes to the United States, the rest to Japan.

Surinam

Although Surinam had the first shrimp processing and freezing plant in the Guianas, it now ranks third in importance in the Guianas fishery. The single shore plant at Paramaribo, Surinam American Industries, Ltd. (SAIL), was acquired from the former owners in 1969 by Bumble Bee Seafoods. The plant is modern, well equipped, and has a processing and freezing capacity of 50,000 pounds of shrimp per day, with a holding capacity of 600,000 pounds. Under an arrangement made in 1956 by the former owners, SAIL enjoys exclusive rights in Surinam to process and export shrimp. This exclusive privilege expired August 31, 1971, at which time other entrepreneurs could enter the field.

To supply SAIL, 49 shrimp vessels operated out of Paramaribo in mid-1971. Of these, 14 flew the United States flag, 15 were Japanese, five Korean, and 15 registered in Surinam. Production of this fleet in 1970 was 4 million pounds of heads-off shrimp, valued at US $5 million.

Expansion plans call for a new operating base and processing plant to serve a fleet of 65 Japanese shrimp vessels, 35 of which would be transferred from Trinidad and 15 from Georgetown.

In recent years about 85 percent of Surinam's shrimp production has been exported to the United States (Table 17).

Table 17.—United States imports of shrimp from Surinam, 1961-71.

Year	Volume	Value
	1,000 pounds	*$1,000 U.S.*
1961	447	278
1962	1,036	969
1963	1,205	1,154
1964	1,323	1,049
1965	1,409	1,112
1966	2,080	1,967
1967	2,129	2,340
1968	3,212	3,857
1969	2,886	3,654
1970	2,582	3,066
1971	2,128	2,656

French Guiana

French Guiana is the closest of the three Guianas to the most productive shrimp grounds. Cayenne, the capital, is the largest of the two coastal ports. Here the most important operation is that of PIDEG (Pecheries Internationales de Guyana Francaise), owned by Henderson's Portion Pak, a division of Borden's (80 percent), and by local French interests (20 percent). PIDEG has a processing and freezing capacity of 40,000 pounds. A total of 42 shrimp vessels supply this plant, all of them U.S. flag. Production of this fleet in 1970 was 3.67 million pounds of heads-off shrimp, valued at U.S. $4.75 million. French Guiana, a prefecture of France, exports little else but shrimp; the shrimp industry represents some 80 percent of the local economy.

A new operation recently started on a small scale is France Peche, affiliated with similar seafood operations in Dakar, Senegal, and Abidjan, Ivory Coast. Starting with two trawlers, with two more expected later in 1972, this company has a small packing room in the public freezer warehouse in Cayenne and handles seabobs and finfish, mainly for export to France.

St. Laurent, the second coastal port, is located near the western border. It served as a base for 30 shrimp boats which supplied a modern and well-equipped processing plant with a capacity of 25,000 pounds daily. Operating and management problems, however, caused this plant to cease operations in 1970. Reportedly, 16 U.S. flag vessels moved from Georgetown to St. Laurent in late 1971, and the plant reopened under new U.S. management.

Table 18.—United States imports of shrimp from French Guiana, 1963-71.

Year	Volume	Value
	1,000 pounds	*$1,000 U.S.*
1963	2,789	1,952
1964	2,961	1,956
1965	3,960	2,958
1966	4,668	4,228
1967	6,717	5,621
1968	7,820	7,624
1969	6,037	6,607
1970	5,802	5,802
1971	3,808	5,561

All of French Guiana's shrimp production is exported to the United States (Table 18).

Brazil

Shrimp are abundant at the northern and southern extremes of the coast. A large fishery exists for the domestic market, but an export industry has been slow in developing.

In a previous regional report from the U.S. Embassy, Mexico City, Milton Lindner, writing in 1956, stated that the annual Brazilian shrimp catch was estimated at 20 to 25 million pounds, live weight. This tremendous production was entirely for domestic consumption. Three separate fisheries account for most of the production. The northern fishery, which contributes about half of the catch, is carried on east of the mouth of the Amazon to near Sao Luiz by means of trap nets and seines, in the estuaries and along the beaches. About 60 percent of the catch is seabobs. The rest is juvenile white and brown shrimps. The finfish trawlers from Rio de Janeiro and Santos take large quantities of adult white, brown, and spotted pink shrimps along the south-central coast, between Rio Doce and Laguna. The large southern fishery is near Rio Grande and is

based on the run of young spotted pink shrimp out of Lagoa dos Patos. This fishery is seasonal and varies from year to year. More than half of the total catch is sold partially dried and heavily salted.

The potential production of Brazil's shrimp resources cannot be determined precisely. According to industry sources, the Brazilian Government, and FAO scientists who have studied the resource, the available resources (especially those in the north which have contributed significantly to the fishery based in the Guianas) should be able to support increased fishing.

The status of the shrimp industry at Belem is described below:

Government Organization: As in the rest of Brazil, the government agency dealing with fisheries is SUDEPE (Superintendency for Fisheries Development). SUDEPE'S Northern Region Office is in Belem. Under the investment incentive plan adopted in Brazil in 1967, the Government of Brazil will invest $3 for every $1 of private capital invested in a SUDEPE-approved fishery project. If the project is also one approved by SUDAN (Superintendency for Development of the Amazon Region), the Government can invest an additional $3. In other words, fishery projects with both SUDEPE and SUDAM approval are eligible for $6 of Brazilian Government money for every $1 of private capital.

In addition to the companies that are already in operation and listed later, SUDEPE has approved two other projects: CAMBELL, an operation involving both shrimp and finfish; and CONORPE, also dealing in shrimp and fish. Both of these projects are expected to be operational in the middle of 1972, and will involve some U.S. capital.

One of the problems limiting fishery development in Belem (and in Brazil as a whole) is the high cost of diesel fuel—about US 25 cents per gallon. This compares with 13 to 15 cents per gallon in the Guiana-area countries to the westward. Legislation has been passed to provide an exemption from the federal tax on diesel fuel for fishing vessel use, thus bringing the price to about that of neighboring countries. The legislation has not been implemented, however, pending the design of a system of control. No date has yet been set for the elimination of the tax.

Shrimp Companies in Belem: At the end of May 1971, the following companies were engaged in the shrimp industry in Belem:

PESCOMAR—Companhia Nacional de Pesca began operations in October 1970; controlling interest is held by Rowan Industries of New Jersey. (Note: This control is accomplished by holding the major part of the common, or voting, stock. SUDAM has 75 percent of the investment.) This is a large, very modern, and well-equipped shrimp processing plant with a freezing capacity of 60,000 pounds per day and storage capacity of 600,000 pounds. Ice-making (flake) capacity is 60,000 pounds per day, with a 150,000-pound storage capacity.

The plant is supplied by six U.S.-built shrimp vessels 86 feet long with on-board freezing equipment. If additional funds requested from SUDAM are forthcoming, this fleet will be increased to 20. In the meantime the company has ordered five smaller shrimp boats from a shipyard in Colombia and plans to operate them on grounds closer in for cheaper operation.

PRIMAR—Productos Industrializados do Mar, S.A., associated with CRUSTOMAR in Santos, Brazil and with Seacrest, Ltd., of the Bahamas. (The company has taken over the plant formerly operated by W.R. Grace and Company.) Like PESCOMAR, this plant is large, modern, and well equipped. Its freezing and processing capacity is 70,000 pounds of shrimp per day, with a storage capacity of 700,000 pounds. Most of its production is exported to the United States, some to Japan.

PINA—Intercambio Comercial, Industria e Pesca, S.A. is internationally connected, with associated operations in Italy, Canary Islands, Spain, and Africa. A site has been acquired, and the building shortly to be constructed will have a freezing capacity of 60,000 pounds per day and a storage capacity of 1,200,000 pounds and will process both shrimp and fish. Plans call for a fleet of 25 vessels to be built in the United States, the first of which was delivered by mid-1971 and two more scheduled for delivery at intervals of 50 days. The vessels are Bender-built in Mobile, Ala., 75 feet long, diesel-powered, and equipped with on-board freezing. Crews and captain will be all Brazilian.

COPESBRA—Companhia de Pesca Norte do Brazil. This company is basically a Japanese operation, with Brazilian participation. It operates three shrimp vessels crewed by Japanese, each with two co-captains, Brazilian and Japanese. Shore facilities consist of a dock, ice plant, and processing and freezing plant.

As an operating base for fisheries, the port of Belem offers a great deal—excellent harbor facilities, shipyard and repair facilities, and propinquity to rich shrimp grounds and to river and marine fish. Under the SUDEPE and SUDAM programs there are attractive incentives for fishery development and investment. As in most Latin American countries, however, built-in bureaucratic customs and delays often present problems to the U.S. citizen not accustomed to doing business in this part of the world. Good business practice obviously calls for a careful and thorough investigation of all aspects of any proposed venture before making a commitment.

Table 19 shows imports from Brazil into the United States and reflects the slow beginning of Brazil's shrimp export industry and its substantial rise during the past 4 years:

Table 19.—United States imports of shrimp from Brazil, 1961-71.

Year	Volume	Value
	1,000 pound	*$1,000 U.S.*
1961	40	28
1962	57	46
1963	7	4
1964	35	19
1965	473	172
1966	486	400
1967	176	155
1968	1,619	1,499
1969	3,707	4,397
1970	2,605	2,707
1971	4,405	5,159

ACKNOWLEDGEMENT

This report is an up-dating and revision of the 1967 original report carrying the same title prepared by Richard S. Croker, the Regional Fisheries Attache for Latin America from 1963 to

1968. In an effort to shorten the report, much admittedly useful and interesting background and historical information has been omitted. Apologies are extended to Richard Croker for this condensation and with grateful acknowledgment for the tremendous amount of work and research that went into the original report.

Thanks are due, too, to the several American Embassies whose Economic and Commercial Officers were so helpful in providing up-dated information when personal visits were not possible. In the countries that the reporting officer visited, these officers and many Government and private people provided valuable help and cooperation.

In the interest of brevity, the list of references contained in the original report will not be repeated here. For those interested, this list can be obtained from the International Activities Staff, National Marine Fisheries Service, U.S. Department of Commerce (Page Bldg.2, Room 249), Washington, D.C. 20235.

MFR Reprint 971. From Marine Fisheries Review, *Vol. 35, Nos. 3-4. Copies of this reprint, in limited numbers, are available from D83, Technical Information Division, Environmental Science Information Center, NOAA, Washington, DC 20235.*

MFR REPRINT 972

California's ocean shrimp industry had over 2 million pounds of landings in 1972, most of it coming from the northern part of the state.

Status of the California Ocean Shrimp Resource and Its Management

W.A. DAHLSTROM

HISTORY OF THE FISHERY

One of the youngest commercial fisheries in California is that for ocean shrimp, *Pandalus jordani.* This species was first fished in California off Morro Bay on April 28, 1952. Later on in the 1950's, fisheries developed off Bodega Bay, Fort Bragg, Eureka, and Crescent City in California and also along the coast of Oregon and Washington.

During 1950 and 1951, exploratory fishing by marine biologists of the California Department of Fish and Game laid the groundwork for utilizing this latent resource. During cruises off the California coast on the research vessel, *N.B. Scofield,* five dense concentrations of ocean shrimp were charted. Regulations for the new fishery were established by the California Fish and Game Commission in 1952, and the first catches were made later that year. Three regulatory areas were designated, catch quotas were established for each area, mesh size restrictions were initiated, and a season was set. The three regulatory areas were Area A, Oregon border south to False Cape; Area B, False Cape south to Pigeon Point; and Area C, Pigeon Point south to Rincon Point (Santa Barbara-Ventura County line). By 1956 it had become apparent that a portion of one of these areas (B) was not being fully utilized. Therefore, it was divided into two areas; B-1 extending from False Cape to Point Arena, and B-2 from Point Arena to Pigeon Point (Figure 1). Each area was allotted separate quotas. Another change occurring in the 1960's was the extension of the Area C boundary from Rincon Point to the Mexican border.

The fishery off Morro Bay in Area C was first to develop. Landings of 197,944 and 198,505 pounds were made in 1952 and 1953 respectively (Table 1). Fishing also took place in Areas A and B (later to be designated B-2), but during

W.A. Dahlstrom is a member of the staff of the California Department of Fish and Game. He is stationed at its Marine Resources Laboratory, 411 Burgess Drive, Menlo Park, Calif. **This paper originally was issued as Marine Resources Technical Report No. 14, 1973, and is reprinted with permission of the California Department of Fish and Game. The photographs were provided by the California Department of Fish and Game.**

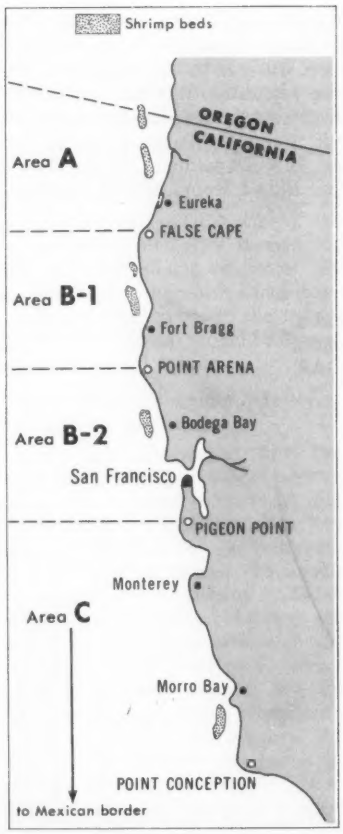


Figure 1.—Fishing areas for ocean shrimp off California.

the same time landings were of a smaller magnitude and ranged from just 4,000 to 45,000 pounds. In 1954 landings declined drastically at Morro Bay and never have since come close to the level of the first two years of fishing. The Area A and Area B (Bodega Bay) fisheries developed quickly and by 1955, 506,433 pounds and 330,681 pounds were landed in these areas respectively. Landings peaked at 450,495 pounds at Bodega Bay in 1957. The landings declined in 1958 and have been sporadic ever since. Area A landings climbed steadily through the late 1950's and early 1960's and reached a peak of 1,860,216 pounds in 1963. From 1964 to 1966 the landings declined to about 1,000,000 pounds per season but started climbing in 1967 and reached a record level of 3,586,370 pounds in 1970. Landings declined somewhat in 1971 and 1972.

The Area B-1 (Fort Bragg) fishery developed in 1957. Landings rose steadily each season and reached a peak of 799,592 pounds in 1961. Since that time the fishery has declined, and only a few thousand pounds have been landed with the exception of the 1972 season, when 102,362 pounds were landed.

The fishery for shrimp occurs during the period from April 15 to October 31 or for a shorter time within the above period if the quota in any area is reached.

Landings and effort have been compiled for all areas since the start of the fishery in 1952. As expected, Area A has had the most effort. Amount of fishing hours per season in this area during the period from 1960 to 1972 has ranged from 1,800 hours in 1964 to 5,947 hours in 1971 (Table 2). The number of vessels has increased steadily to a high of 26 in 1971. Highest catch per hour on record for Area A is 1,217 pounds, attained in 1968.

Market samples of ocean shrimp are taken to determine carapace length, sex, age, and heads-on count per pound. Most of the shrimp in the fishery are in the second and third year of life (I+ and II+). Comparisons of carapace lengths by year from 1969 to 1972 by year class in Area A show different growth rates. The 1969 year class in 1970 was definitely larger compared to other one-year-old shrimp during the period from May to August (Table 3). Over the same time period the odd year classes of 1967 and 1969 were one to two millimeters larger than the even year classes of 1968 and 1970 as two-year-old shrimp.

Ocean shrimp, when caught, range in age from six months to about four years old in California. They do not reach marketable size until they are a year old. When they have completed spawning at about three years of age, they die in great numbers and thereafter contribute a minor percentage to the fishery. Very few survive to their fourth birthday or beyond.

REGULATION AND MANAGEMENT

Otter trawls and beam trawls are legal gear used to catch ocean shrimp. From 1952 to 1962, shrimp fishermen were limited to the use of beam trawls. In 1963 fishermen were permitted to use otter trawls. Since that time no beam trawls have been used. The minimum mesh size of the net is 1.5 inches stretch measure between the knots. It was felt that this mesh size provides greater escapement of the small one-year-old shrimp.

The season starts on April 16 and ends on October 31 or earlier if the quota is reached. This time period corresponds with the time when most of the females are not carrying eggs and forms the basis for the season.

Quotas proposed for the 1973 season are 3.2 million pounds for Area A and 250,000 pounds each for Areas B-1, B-2 and C. The quota for Area A since 1969 has been established by a population model designed by Department of Fish and Game statisticians. The model estimates population size and safe harvest levels. Quotas in the other areas have remained at 250,000 pounds each since 1962.

Table 1. Ocean Shrimp Landings (in Pounds) by Area.

Year	Area A	Area B-1	Area B-2	Area C	Total
1952	3,876	—	3,665	197,944	205,485
1953	27,484	—	45,343	198,505	271,332
1954	168,881	—	112,751	8,510	290,142
1955	506,433	—	330,681	1,442	838,556
1956	895,596	—	272,583	closed	1,168,179
1957	694,978	228,097	450,495	260	1,373,830
1958	1,142,274	324,839	172,804	88,763	1,728,680
1959	1,327,402	443,282	86	14,544	1,785,314
1960	1,303,922	529,652	110,252	74,831	2,018,657
1961	1,203,117	799,592	180	—	2,002,889
1962	1,537,458	250	245,247	—	1,782,955
1963	1,860,216	27,700	204,957	190	2,093,063
1964	932,133	1,210	34,982	—	968,325
1965	1,164,221	4,200	252,663	—	1,421,084
1966	1,182,421	3,750	520	506	1,187,197
1967	1,407,280	275	888	—	1,408,443
1968	2,079,110	—	190,810	—	2,269,920
1969	2,947,563	—	—	—	2,947,563
1970	3,586,370	—	298,769	66,695	3,951,834
1971	3,077,248	525	700	2,110	3,080,583
1972	2,118,527	102,362	213,452	—	2,434,341

BIOLOGICAL DATA

Distribution

Ocean shrimp are found from Unalaska to San Diego, California at depths of from 120 to 1,500 feet. In California, the species is generally found from depths of 240 to 750 feet over a green mud of mixed mud and sand bottom.

Migration

Migrations of this species appear to be mostly local. Adults from the different beds probably do not intermix but the planktonic larvae may be carried long distances and could conceivably intermingle with those of closely associated beds. Seasonal migrations of adults either inshore or offshore and also coastwise have been noted within the confines of the bed. Even during the fishing season distribution shifts have been observed according to location of fishing effort. This species is very gregarious and its schooling habits generally enable the fishermen to obtain good comparative catches of pink shrimp with very few fish and other invertebrates. Night and day trawling has detected evidence of diurnal vertical movements; this resulted in excellent catches during the day and poor catches at night. Movement off the bottom also has been demonstrated by midwater trawl catches off Vancouver Island, British Columbia and by suspended trap catches in midwater depths off the coast of Oregon. These migrations may extend to the surface and may be associated with feeding activities on plankton.

Life History

Most ocean shrimp are protandric hermaphrodites. The normal pattern is for an individual to mature and function as a male during the second or third year of life and then change sex, mature, and function as a female. However, deviations from this normal pattern have been noted, with the appearance of primary females (nonhermaphroditic) during the second year of life. During some years, a large percentage (up to 70 percent) of the one-year-old shrimp become females and never function as males.

Table 2. Area A Landings, Effort and Catch per Hour.

Year	Landings (Pounds)	Effort (Hours)	Pounds/Hour	Vessels
1960	1,328,400	2,489	533	12
1961	1,206,847	1,924	627	9
1962	1,540,700	3,193	483	12
1963	1,862,341	3,813	488	14
1964	944,020	1,800	524	7
1965	1,167,941	2,706	431	15
1966	1,209,183	2,684	450	11
1967	1,403,124	1,953	718	12
1968	2,031,280	1,669	1,217	14
1969	2,951,840	4,463	661	23
1970	3,602,925	4,717	764	20
1971	2,678,250	5,947	450	26
1972	2,126,661	3,435	619	18

Gonads begin developing during the summer, and in the autumn the maturing bluish-green ovaries are visible within the carapace. At the last molt preceding spawning, the pleopods of the female develop special ovigerous setae.

Mating takes place during September and October and fertilization, which is probably external, takes place when the females begin extruding eggs in October. After the eggs are fertilized, they are attached and are interconnected by a network of mucous threads. The color of the eggs when first spawned is a bluish-green. With the gradual development of the egg, the color fades to a light green with a tint of gray.

The usual number of eggs carried by a female is between 1,000 and 3,000. Small individuals in their second year of life have been found carrying as few as 900 eggs, whereas larger individuals in their third or fourth year of life have been found with up to 3,900 eggs. The larger and older females generally carry more pleopods. Females carry the eggs on posterior swimming appendices until the larvae hatch. The peak of hatching occurs during the last part of March and first part of April. The ovigerous period ends about the first part of May in northern California and about the last part of May in the Morro Bay area.

According to laboratory studies, the larvae pass through 11 to 13 zoeal stages to complete metamorphosis to the juvenile stage. Duration of the various larval stages ranged from 4 to 12 days, with an average of 6.8 days. One shrimp completed metamorphosis in 79 days, after passing through 11 zoeal stages. Two others were in the 12th and 13th zoeal stages and were 74 and 85 days old, respectively, when they died. The first indication of the settlement of juvenile shrimp on the beds is generally during July. Trawling at this time with small mesh nets in Area A has produced some of these "O" year class shrimp. Generally they become more abundant toward fall.

Size, Age and Growth

Growth rates for ocean shrimp vary according to region, and also by sex and year class. In California ocean shrimp reach an average size of about 9 mm carapace length after 6 months from larval release.

After 12 and 24 months they average 13.7 mm and 19.2 mm respectively in size. Then after 36 months they average 22.2 mm. Comparison of growth rates in Areas A, B-1 and B-2 in California show very little difference. However, in com-

Table 3. Average Carapace Length (mm) of I- and II-Year-Old Shrimp, 1969-1972 Seasons.

	I				II			
Season (Year Class)	1969 (1968)	1970 (1969)	1971 (1970)	1972 (1971)	1969 (1967)	1970 (1968)	1971 (1969)	1972 (1970)
April				12.21				17.41
May	14.47	14.64		12.48	20.0	18.39		17.41
June	14.75	15.21	13.59	13.41	20.6	18.75	20.14	17.94
July	15.19	15.76	14.82	14.99	20.7	19.10	20.83	18.78
August	15.46	16.34	15.49	15.61	20.8	19.52	21.18	19.26
September			16.24	16.06			21.49	19.69
October			16.56	16.07			21.68	19.63

parison with growth rates of shrimp from Vancouver Island, British Columbia, the California shrimp grew at a faster rate. They averaged about one mm larger from the age of 6 to 36 months. Growth rate of the species off Washington and Oregon appears to be somewhat slower than off British Columbia and California. However, the Oregon and Washington shrimp grow at least one year older than the California shrimp.

In spite of the variations in growth rate which have been mentioned, there is a clear pattern of seasonal growth. During the first summer, growth is rapid; it slows down slightly during winter, but resumes at a rapid pace in the second spring and summer until about August, when growth of males retards. Growth during this period (from the first to the second summer) averages about 1 mm carapace length increase per month. The growth of the transitionals proceeds during the second autumn at the same rapid rate until about the end of October. At this time most transitionals have become females, and, when the sex change is completed, growth virtually ceases. Some shrimp remain male until the following year; such specimens grow more slowly than the transitionals and females during the second summer and autumn.

Differential growth between the sexes results in a bimodal size curve for the same year class. Both males and females grow slowly during the winter months (the females actually stop growing during the ovigerous period). In the spring, when the shrimp are approximately 2 years old, growth in males accelerates earlier than in females, and many of the larger males begin to change sex. Females, which had changed sex the previous year, resume growth in the early summer, after the ovigerous period. By November, at the age of about 2.5 years practically all members of the year class are females and are entering the ovigerous period. Determining growth rates and age of females after this time is very difficult because of the reduced growth rate and apparent high natural mortality.

Mortality

Mortality rates appear to vary from year class to year class, as well as from season to season. Estimates of natural mortality in Area A between fishing seasons (over winter) indicate that 36 percent, 76 percent, and 43 percent survive during their first, second, and third winter of life, respectively.

Estimates of total mortality rates of the shrimp population in Area A from April 1960 to April 1966 ranged from 48 to 70 percent with a mean of 61 percent.

The effects of physical factors, such as salinity and temperature, upon shrimp mortality is not known. Predators appear to be a major factor in natural mortality. In years of good shrimp recruitment, many fish species, such as hake, sablefish, arrowtooth flounder, spiny dogfish, and skates, can be found feeding heavily on young shrimp.

Receiving shrimp trawl net aboard the *Theresa S.*, Bodega Bay.

DISCUSSION

Status of the Resource

The status of resource in Area A looks questionable. In the past it has produced high yields supported by strong recruitment from the 1966, 1968 and 1970 year classes. Although a fairly high catch per hour of 619 pounds was attained in 1972 the fishermen experienced difficulty finding and staying on good concentrations of shrimp. Consequently they were unable to attain the quota of 3.2 million pounds. It appears that strong recruitment from the 1972 year class is needed to support the 1973 fishery.

The resource in the other areas appears to be too small to support fisheries with large quotas. The resource has not demonstrated any capability of sustaining these fisheries even with a 250,000 pound quota. Natural mortality appears high and this may preclude the ability of the resource to provide a sustained yield fishery. Strong continuous recruitment is needed for these fisheries to become productive again.

Research Needs

(1) An understanding in regard to the extent of immigration and emigration of shrimp populations in northern California and southern Oregon.
(2) Develop methods to incorporate natural mortality rates and recruitment in population model.
(3) Investigate the effect of the present 1.5 inch mesh size regulation in terms of escapement and contribution of shrimp to the total resource.

REFERENCES

Dahlstrom, Walter A. 1961. The California ocean shrimp fishery. Pac. Marine Fish. Comm. Bull., 5:17-23.

———. 1967. Synopsis of biological data on the ocean shrimp *Pandalus jordani*, Rathbun. FAO World Scientific Conference on the Biology and Culture of Shrimps and Prawns, Mexico. FAO Fisheries Report No. 57, Vol. 4:1377-1416.

Dahlstrom, Walter A. and Daniel W. Gotshall. 1969. Will the shrimp boats keep a comin? Outdoor Calif. 30(3):1-4.

Gotshall, Daniel W. 1967. The use of predator food habits in estimating relative abundance of the ocean shrimp, *Pandalus jordani*, Rathbun. FAO World Scientific Conference on the Biology and Culture of Shrimps and Prawns, Mexico. FAO Fisheries Report No. 57, Vol. 4:667-685.

_____. 1972. Estimates of population size, mortality rates and growth rates of northern California ocean shrimp, *Pandalus jordani*, 1965-1968. Calif. Dep. Fish and Game, Fish. Bull. (155):1-47.

Milburn, Gary and Jack C. Robinson. (In Press). The vertical distribution and migration of pink shrimp *(Pandalus jordani)* off Oregon. Oregon Fish Comm.

Emptying ocean shrimp catch aboard the *Theresa S.*, Bodega Bay.

MFR Reprint 972. From Marine Fisheries Review, *Vol. 35, Nos. 3-4. Copies of this reprint, in limited numbers, are available from D83, Technical Information Division, Environmental Science Information Center, NOAA, Washington, DC 20235.*

Alaska's shrimp landings have increased 40-fold in only 15 years.

Alaskan Shrimp Fisheries

Commercial fishing for pandalid shrimp in Alaska began in 1916 in the southeastern area near Petersburg and until 1958 was confined almost exclusively to southeastern Alaska. This area's catch has remained relatively stable at 1 to 2 million pounds, except for the late fifties and early sixties when it peaked at 7.6 million pounds. The fishing here is mostly with the beam trawl and is centered in inside waters near Wrangell and Petersburg.

The shrimp fishing began in central Alaska in the late fifties, but the initial effort consisted mainly of exploratory efforts by local fishermen in the Cook Inlet and Kodiak areas. Full-scale shrimp operations in central Alaska began in 1959, when a catch of 2.9 million pounds was landed at Kodiak. Since that time the catch has increased dramatically to a record 95 million pounds in 1971 (Table 1). The greatest portion of the central Alaska shrimp fishery is in the Kodiak area, but the fishery is actively expanding to the west along the Alaska Peninsula to the eastern Aleutian Islands. The primary gear used in central Alaska is the otter trawl.

Soviet and Japanese fleets both began shrimp fishing off the Alaska coast in 1961. The Japanese fleets operated mainly in the Bering Sea north of the Pribilof Islands, and the Soviets fished in the Gulf of Alaska off Shumagin Islands and Portlock Bank. Catches by the foreign fleets in these waters exceeded the total domestic catch until 1967 (Table 1) when the law creating the 9-mile contiguous fishery zone seaward of territorial waters was passed. This law protected most of Alaska's shrimp resources, because the fishing areas lie relatively close to shore. Other reasons for the increased catches beginning in 1967 were economic such as improved processing techniques and a steadily increasing domestic market.

Because the rapid expansion of the central Alaska fishery led to concern among local fishermen and processors about the possible depletion of the resource, catch quotas were initiated in the Kodiak and Kachemak Bay (Cook

Table 1.—Domestic and foreign shrimp catches off Alaska, 1951-72 (in thousands of pounds).[1]

Year	S.E. Alaska	Central Alaska	Total Alaska	Japan	USSR
1951	1,707	1	1,708	—	—
1952	1,944	9	1,953	—	—
1953	1,722	12	1,734	—	—
1954	1,438	14	1,452	—	—
1955	1,777	51	1,828	—	—
1956	3,032	12	3,044	—	—
1957	2,350	30	2,380	—	—
1958	7,606	256	7,862	—	—
1959	5,519	7,534	13,053	—	—
1960	3,343	4,093	7,436	—	—
1961	4,212	11,768	15,980	22,500	300
1962	3,884	13,059	16,943	46,200	600
1963	3,110	12,017	15,127	69,500	700
1964	2,793	4,934	7,727	45,100	9,000
1965	2,945	13,874	16,819	15,300	15,400
1966	3,785	24,408	28,193	7,500	23,100
1967	2,803	39,010	41,813	9,500	25,100
1968	2,104	39,919	42,023	2,900	6,300
1969	1,680	46,171	47,851	—	11,700
1970	958	73,298	74,256	—	9,300
1971	960	93,931	94,891	—	10,400
1972	910	80,352	81,262	—	5,100

[1] The catch figures are from documents published by the National Marine Fisheries Service and the Alaska Department of Fish and Game.

Left—A rain of shrimp. A container is being unloaded at a processing plant in Kodiak.

Above—Kodiak, the largest fish port in Alaska.

Inlet) areas in 1971. The Kachemak Bay quota was set at 5 million pounds annually; the quotas for the Kodiak area for 1971 and 1972 were 88 and 86.6 million pounds respectively, and 55 million pounds is proposed for 1973. The 1971 and 1972 Kodiak area catch quotas were not achieved because processing had to be stopped because of water shortages. In addition, in 1972 a fisherman's strike for higher prices coupled with emergency orders of the Alaska Department of Fish and Game reduced fishing time.

Over the years, the techniques of processing and the type of the end product have changed considerably. Early in the history of the industry, almost all of the shrimp were canned; for a short period frozen shrimp logs were made from the broken pieces. At present, the industry produces a mixture of high quality canned and frozen products, which have an almost unlimited market.

MFR REPRINT 973

Beautiful Kachemak Bay in Alaska is the site of NMFS studies designed to further understanding of Pandalus borealis, *the chief shrimp species in the Alaskan catch.*

Pandalid Shrimp Life History Research at Kachemak Bay, Alaska

JAMES C. OLSEN

Pandalid shrimp stocks in the Gulf of Alaska are a resource that currently requires short-term and long-term studies so that effective management models can be developed and the effects of potential environmental changes can be evaluated. The stocks are heavily exploited, but little is known about the effect that fishing has on the shrimp or about how fluctuations in environmental factors are related to year-class abundance. It is possible, for instance, that fluctuations in year-class strength rather than fishing effort may ultimately determine levels of yield. Many investigators have shown that marine invertebrates, particularly short-lived species, usually have widely fluctuating levels of year-class success. This is especially marked in species whose larval stages are planktonic and at the mercy of the vicissitudes of the oceanic environment. Pandalid shrimp are relatively short-lived (5-7 years), in comparison with some other kinds of shellfish, but have relatively long planktonic larval periods (up to 3 months). It is likely, therefore, that the cyclical nature of most pandalid shrimp fisheries is closely related to year-class success.

Although pandalid shrimp are fished in many areas of the world and numerous life history studies have been done on *Pandalus borealis,* the most important commercial species, there have been limited studies to determine the effect of a fishery on a pandalid stock or the role of the environment in governing year-class strength.

This lack of information continues to hamper management in setting regulations to protect this valuable resource in Alaska. The growth of the fishery continues to outpace research, primarily because long-term studies are required to establish life history information that relates to determining how fishing affects the resource.

James C. Olsen is a member of the staff of NMFS Auke Bay Fisheries Laboratory, Auke Bay, Alaska.

The NMFS Auke Bay Fisheries Laboratory has responded to the need for research by studying the dynamics of shrimp stocks in Kachemak Bay, Alaska (Figure 1). Kachemak Bay, an arm of lower Cook Inlet, is 42 miles long and 21 miles wide at the mouth and 3.5 miles wide at a constriction formed by the intrusion of Homer Spit (Figure 2). The northwest shore consists of shallow

Figure 1.—Alaska, showing location of Kachemak Bay.

mudflats, which run up to cliffs of sand and clay of about 500 feet elevation (Figure 3). The southeast shoreline borders the deeper side of the bay and consists of mountainous glacially eroded hardrock indented by many sheltered passages, islands, and deep bays. The bay is relatively shallow; the average depth is 165 feet and the maximum is 545 feet. Mixing, due to tidal action, is a dominant feature and involves water transport from the Gulf of Alaska into the bay.

Kachemak Bay has been used by the Auke Bay Laboratory as a study area for shellfish research since 1957. A field station has been developed on the south shore of Kachemak Bay at Kasitsna Bay (Figure 4) and is managed by a resident biologist. Kachemak Bay was chosen

Figure 2.—Kachemak Bay viewed from the northwest shore. Homer Spit is in the foreground and the mountainous southeast shore in the background.

for field studies because of its accessibility to clean salt water for laboratory studies and because it has year-round commercial fisheries for king, tanner, and Dungeness crabs, shrimp, salmon, and halibut. Kachemak Bay has supported commercial fish and shellfish fisheries for many years and has recently gained importance as a recreational area for boating, clam digging, crabbing, and sport fishing. The existence of a variety of fish and shellfish stocks makes the bay valuable as a marine study area.

The total area of Kachemak Bay (250 square miles) is small enough to permit comprehensive sampling with limited amounts of equipment and personnel. Industrial developments are present and others are proposed for the area. One sawmill operates in the area and three fish-processing plants are present. Oil and natural gas reserves are present and may be developed in the near future.

The current shrimp research activities in Kachemak Bay will provide insight into the life history, population dynamics, and behavior of pandalid shrimp in the Gulf of Alaska. The general objectives of the research on larval and postlarval shrimp are to (1) increase knowledge about pandalid shrimp life history stages, behavior, and population dynamics; (2) determine how fishing affects shrimp stocks; (3) determine the causes of annual fluctuations in shrimp stock abundance; (4) describe and quantify the characteristics and ecology of environments inhabited by shrimp; and (5) increase the understanding of the role pandalid shrimp have in the organic production system of the North Pacific.

Figure 3.—Northwest shore of Kachemak Bay viewed from the Kasitsna Bay field station.

Studies designed to answer these questions began in May 1970 with weekly sampling of the commercial shrimp catches. This sampling, which is continuing with participation by the Alaska Department of Fish and Game, provides estimates of the species, size, and sex-specific catch rates, along with life history data such as growth, onset of maturity, and hatching times. The first stock assessment was made in October 1970 by trawl survey; second and third assessments were made in May 1971 and 1972; and a fourth survey is planned for May 1973.

The data from stock assessment surveys and catch sampling are providing growth, recruitment, mortality, and other life history information primarily for *P. borealis* and *P. goniurus*. Similar data for other pandalid species are also obtained, but the information has not been as complete because of the difficulty in sampling rocky habitats. Results from our studies will be used to develop mathematical models of the dynamics of pandalid shrimp populations.

Studies of shrimp larvae are also underway at Kachemak Bay. These studies began in 1971 and have provided data on (1) time and place of larval hatching, (2) diurnal vertical distribution of larvae, (3) preliminary estimates of larval survival, and (4) annual larval production and number of females hatching larvae.

The work in progress includes creating a reference collection of larvae representing various species and developmental stages. The identification and description of larval stages will be accomplished by using culture techniques and field collections.

The Auke Bay Laboratory's shrimp research program is conducted in close cooperation with the Alaska Department of Fish and Game, and the results are assisting the State in making management decisions—particularly in defining the size of annual quotas. As the analyses are completed, the results are expected to find application to areas of Alaska other than Kachemak Bay.

Figure 4.—Kasitsna Bay field station. The four buildings in the foreground are laboratory work areas and storage facilities. The two large buildings in the background are permanent living quarters.

MFR Reprint 973. From Marine Fisheries Review, *Vol. 35, Nos. 3-4. Copies of this reprint, in limited numbers, are available from D83, Technical Information Division, Environmental Science Information Center, NOAA, Washington, DC 20235.*

MFR REPRINT 974

The spot shrimp is the largest in the North Pacific, mature individuals reaching 12 inches long. Studies of the juveniles are being conducted by NMFS scientists in Alaska.

Studies of Spot Shrimp, *Pandalus platyceros*, at Little Port Walter, Alaska

LOUIS BARR

The spot shrimp, *Pandalus platyceros*, is the largest shrimp found in the North Pacific—large individuals may reach 30 cm (12 inches) in length and weigh up to 120 g (one-fourth pound). Spot shrimp are important predators on many of the smaller animals that share their environment and in turn are an excellent food for many of the larger marine animals and for man.

Juvenile spot shrimp have been studied since 1967 at Little Port Walter on southern Baranof Island, southeastern Alaska. The study began after NMFS biologists exploring for shrimp concentrations in the area found many young spot shrimp in the inner part of the Little Port Walter estuary. The location lent itself perfectly to the study because of the existing fishery research station, which has served as a center for salmon studies since 1934.

Initial observations by biologist-divers and results of pot fishing showed that only juvenile spot shrimp were present in the inner bay of Little Port Walter. The inner bay is a small body of water—about 750 m long and 450 m wide, with a maximum depth of 21 m—and within the bay, the spot shrimp inhabit only the relatively hard-bottom, kelp-covered periphery. The behavior of the shrimp was clearly regulated by the daily periods of light and dark—during daylight they remained inactive and hidden under kelp fronds or in crevices among the rocks; at night they were out in the open and foraging actively for food on the bottom.

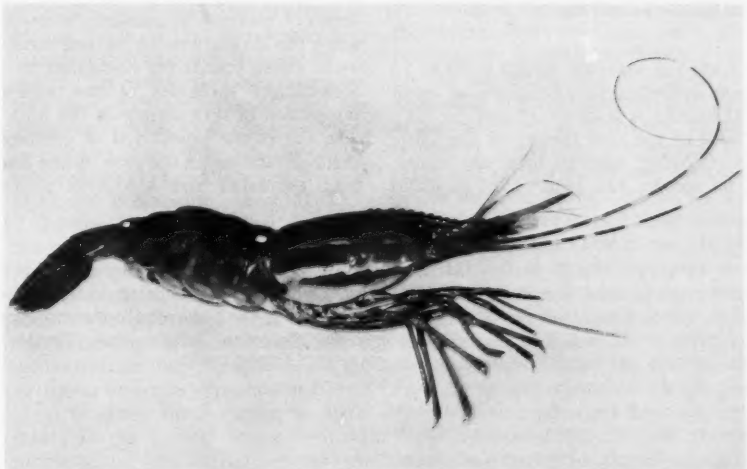
Louis Barr is a member of the staff of the NMFS Auke Bay Fisheries Laboratory, Auke Bay, Alaska.

Alaska, showing location of Little Port Walter.

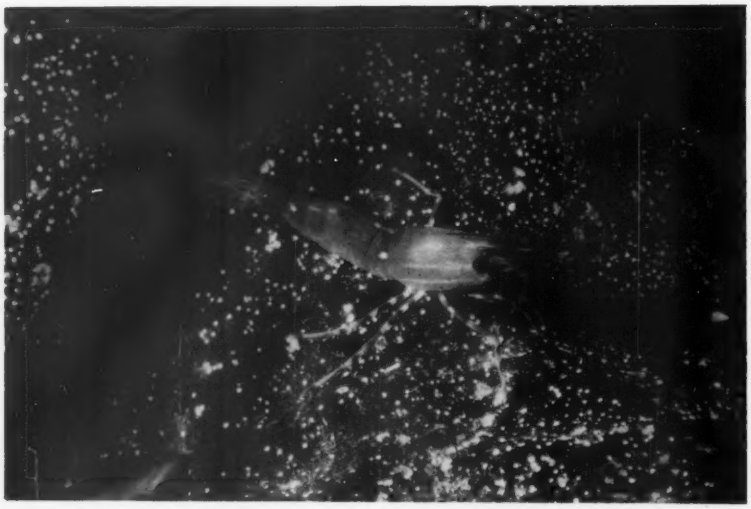
The study of the juvenile spot shrimp at Little Port Walter was designed to answer several important questions about the species. First, what was the role of an area such as Little Port Walter in the early life history of the spot shrimp? Second, how many shrimp were in the bay and what were the dynamics of the population? Third, what were the behavior and ecological relationships of the shrimp while in the study area?

The inner bay at Little Port Walter serves as a nursery area for young spot shrimp—only small juveniles are ever seen in the bay. The shrimp, hatched during the early spring in the deep-water environment of the adults, enter the shallow nursery area during their first summer after passing through their planktonic larval stages. They then remain in the bay through their first fall and winter and second spring and summer. Sometime during their second fall and winter when they are 19 to 23 months old, they all emigrate from the bay, apparently seeking the 60- to 200-m water in which the adult spot shrimp are usually found.

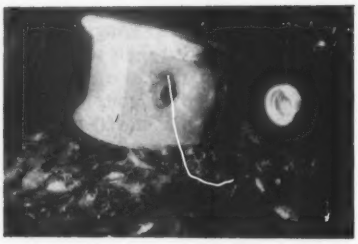
The spot shrimp are extremely small when they enter the nursery area. The smallest, collected in July, have a carapace length of only 3 or 4 mm. At 1 year



The spot shrimp is the largest shrimp species inhabiting the North Pacific Ocean. Large females like the one above may reach a foot in length (excluding the antennae) and one-fourth pound in weight.



Hidden and inactive during the day, young spot shrimp actively forage for food at night. The shrimp above was photographed at night while on a heavily encrusted kelp frond.



A diver observes the behavior of a group of spot shrimp near a baited trap.

of age the carapace length is about 15 mm, and when they emigrate, at about 20 months, it is about 25 mm.

All of the spot shrimp in the Little Port Walter nursery area are males. This species, like most of the pandalid shrimps, is protandrically hermaphroditic. All individuals develop first as males; after maturing and functioning as males, at about 3 to 5 years they transform to females and remain that sex for the rest of their lives. Therefore, with few exceptions, all of the small spot shrimp are males and all of the large ones are females.

The number of spot shrimp in Little Port Walter vary widely from year to year. Index counts of shrimp abundance are made periodically by divers along a series of established transects at night when the shrimp are active and easily seen. These counts are converted into area-density estimates of the entire population of spot shrimp in the area. The size of the population of yearling shrimp in the bay in the early spring has been estimated from a high of about 66,000 in 1972 to a low of about 11,000 in 1967. This sixfold difference in year class strength within this one nursery area may be indicative of the magnitude of the annual variability in recruitment to the populations of adult shrimp.

The behavior and the ecological relationships of the spot shrimp in Little Port Walter have also been investigated, principally by direct observations by night-diving biologists. In addition to the nocturnal nature of this species, much has been learned of the spot shrimp's feeding behavior, associated species, and substrate preference. The shrimp are carnivorous and feed both by scavenging dead animal material and by preying on living organisms such as amphipods, euphausiids, limpets, annelids, and other shrimps. Among the dozens of species of vertebrate and invertebrate animals commonly found associated with the young spot shrimp, another pandalid, the dock shrimp, *Pandalus danae*, is the most consistent. Spot shrimp in the nursery area may be found on substrates ranging from bedrock to muddy sand; the principal requirement seems to be that there be adequate cover to provide daylight hiding places. Heavy coverings of the low kelps such as *Laminaria* sp. and *Agarum* sp., sunken wood debris, or even artificial materials all provide acceptable cover for the shrimp.

Future studies of the spot shrimp at Little Port Walter will include continued monitoring of year class strength and an attempt to locate the adult population to which the young shrimp are recruited. The latter work, relying on future recovery of shrimp marked and released within the nursery area, should help to tie the studies at Little Port Walter into a more complete understanding of the total life history of the spot shrimp.

MFR Reprint 974. From Marine Fisheries Review, *Vol. 35, Nos. 3-4. Copies of this reprint, in limited numbers, are available from D83, Technical Information Division, Environmental Science Information Center, NOAA, Washington, DC 20235.*

MFR REPRINT 975

"How close are we, with today's technology to commercial farming of shrimp?" An NMFS scientist takes a close look at...

Progress Toward Farming Shrimp in the United States

RICHARD A. NEAL

Although no commercially viable penaeid shrimp farms exist at present in the United States, the strong demand and resulting high prices for shrimp are incentives for development of economical farming practices. Several large firms and a number of smaller groups are operating shrimp hatcheries and farms on a developmental basis in efforts to reduce costs and thereby make shrimp-rearing a profitable business. Shrimp culture has been a profitable enterprise for years in some parts of the world, such as Southeast Asia and Japan, where economic circumstances are different from those in the United States.

A number of State, University, and Federal research groups in the United States are contributing to the rapidly accumulating pool of information concerning shrimp farming. Major contributions to our technical knowhow in this field have been made by Texas A&M University, Texas Parks and Wildlife Department, NMFS Galveston Laboratory, Louisiana Wild Life and Fisheries Commission, Nicholls State College, Louisiana State University, the University of Miami, and the University of Georgia. Much of this research has been directed toward methods of rearing shrimp from postlarvae to market size in ponds; however, research is also underway on many aspects of shrimp biology, physiology, and nutrition.

Since 1970, Richard A. Neal has been leader of the shrimp culture research group at the NMFS Gulf Coastal Fisheries Center, Galveston Laboratory, Galveston, Tex.
This paper is Contribution No. 362 from the NMFS Gulf Coastal Fisheries Center, Galveston, Tex.

How close are we, with today's technology, to commercial farming of shrimp? Unfortunately, the research groups working with shrimp farming have produced very little information on production costs. The emphasis so far has been on finding ways to rear shrimp at high densities. Because the research has required experimentation with many factors, accurate costs are difficult to obtain. Cost data developed by industry in its pilot-scale operations are considered proprietary and are generally not available to the public.

We do know approximately what quantities and sizes of shrimp can be produced and the amount of time required to rear shrimp using several different approaches. Shrimp can be reared fairly easily to a size of about 4 inches (the size they normally leave the estuaries) in ponds. Production (single crop) of these small shrimp in static ponds in the United States with no supplemental feed or fertilizer has averaged about 100-150 lb (heads-off) per acre. Fertilization of the ponds with inorganic or organic fertilizer will generally add roughly 100 lb (heads-off) per acre to the crop. Feeding may add an average of fifty to several hundred additional pounds (heads-off) per acre depending upon the feed used and the amount fed. Continuous exchange of water will increase production beyond these levels in some instances; however, restrictions on effluents from aquaculture many prohibit the use of this method.

Since the market value of 4-inch shrimp is low (average price, heads-off in 1972 was $0.47 per lb), considerable effort has gone into developing methods of rearing shrimp to a larger, more valuable size. Usually growth rates of captive shrimp decrease when shrimp reach sizes of 3-5 inches, depending in part upon the density of shrimp in the ponds. Typical growth rates in captivity for the Gulf species of shrimp at temperatures of 26°-30°C are presented in the following table.

Size	Days after hatching
0.25 inch (postlarvae)	10-14
1 inch	25-35
4 inch	75-130
5 inch	100-150

These rates are only approximate since growth varies drastically depending upon environmental conditions and availability of food. Growth of shrimp larger than 5 inches is slow and inconsistent on feeds presently being used.

The decision of when to harvest is an economic one based on growth and mortalities of the shrimp, the value of the shrimp, labor and feed costs, and the time the farmer's facilities are tied up. An interesting way of viewing the economics of shrimp farming is to look at the value of an individual shrimp (Figure 1). Prices used in this graph are retail bait shrimp prices and dockside prices for food shrimp. Postlarvae for stocking will cost a farmer between one-half and one cent each in the United States. Even if mortality rates are low, the farmer will have to raise food shrimp well beyond the 4-inch size to recoup his expenditures for postlarvae. He must also consider the cost for facility, food, and operation. Clearly, the only logical approaches from an economic viewpoint are (1) rear shrimp for the bait market to take advantage of the good early growth in ponds and the possibility of harvesting several crops a

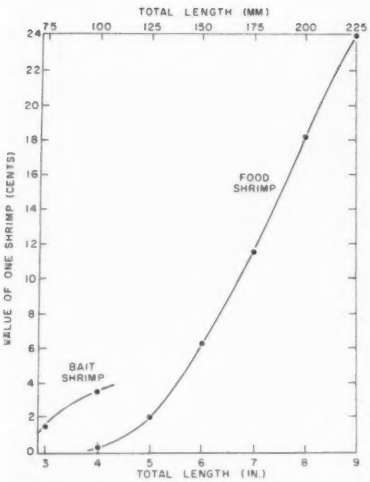


Figure 1.—Value of individual shrimp of different sizes for live bait and for food, based on July 1972 prices.

year or (2) raise the shrimp to a relatively large size to take advantage of the higher price per pound.

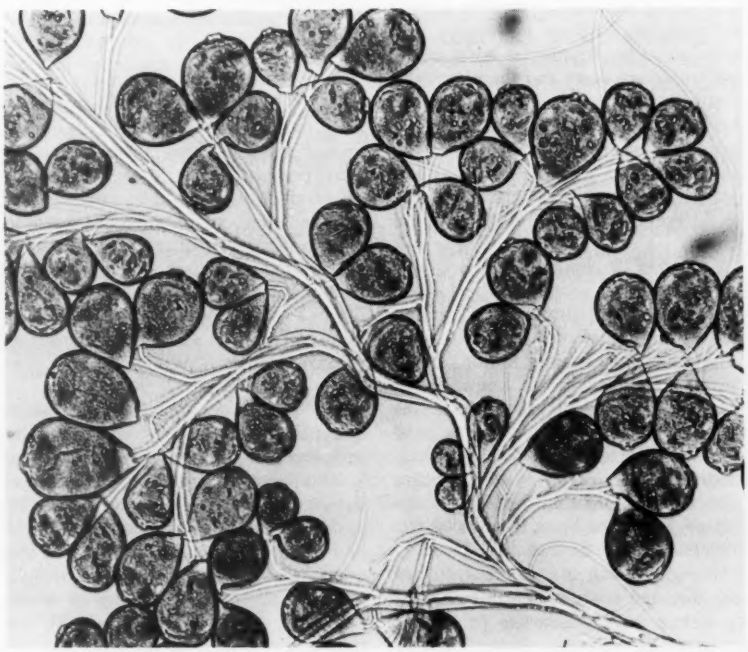
Since mortality rates are so important, we need to examine them more closely. Typical survival in pond-rearing experiments from postlarvae to the 4-inch size has been about 50 percent with a range of 0 to nearly 100 percent. Characteristically, survival is extremely variable and reasons for mortalities are very poorly understood. With present prices for postlarvae these mortalities are intolerable from the shrimp farmer's point of view.

Research related to shrimp culture presently underway at the Galveston Laboratory is directed toward the solution of several key problems which will help make shrimp farming a reality. Early work in Galveston was oriented primarily toward the development of economical hatchery techniques. Dependable methods for mass culture of larvae in small tanks were perfected in Galveston and several commercial groups are presently using these methods. The availability of a constant supply of uniform postlarvae opened the door for research in several other key areas. At present, work at the Galveston Laboratory is directed toward the solution of problems in the following four areas: (1) finding a dependable method for maturing female shrimp in captivity, (2) developing economical feeds which will provide the nutritional needs of shrimp, (3) developing methods for the recognition, prevention, and treatment of shrimp diseases, and (4) developing methods for the intensive culture of shrimp in closed systems.

Since female shrimp do not mature sexually in captivity, major emphasis has been placed on determining why. Obvious factors which differ between the offshore environment where wild shrimp do mature and the ponds where they do not are foods and environmental factors such as temperature, light, salinity, water quality, and pressure. These factors are all being examined in controlled laboratory experiments to determine their importance in sexual maturation. After numerous experiments, the first indication of success was observed in tanks held at a high pH. Egg production began in these shrimp and is continuing although the animals are not yet sexually mature. We hope this initial success will be a key to establishing procedures for the routine production and spawning of mature female shrimp.

A second approach to the maturation problem, a study of shrimp hormones, is being pursued simultaneously. Because the developmental process in shrimp is regulated by hormones, ovulation could conceivably be induced through injection of hormones if proper hormones were available. We are presently isolating and identifying hormones suspected to play key roles in sexual maturation. When they have been identified, the hormones or synthetic analogs can be injected experimentally in an effort to induce sexual maturation of female shrimp on demand.

Once maturation of shrimp in captivity is possible, culture will be simplified and the probability of economical farming of shrimp will be increased. Not only would larval production costs be reduced through elimination of the necessity of capturing wild females, but a dependable supply of spawners would be available at all times of the year.



A stalked protozoan which lives on shrimp and may interfere with respiration when the gills are affected.

In addition, selective breeding programs could be initiated and new, improved breeds of shrimp could be reared which are better adapted to culture than the wild stocks.

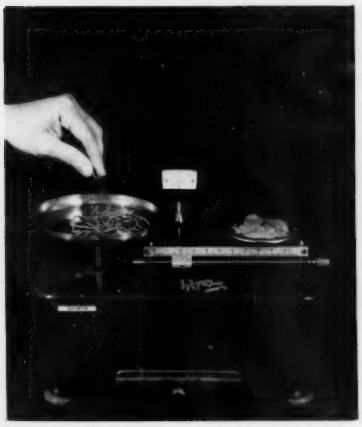
Shrimp nutrition is poorly understood even though considerable research on the subject has been conducted in the United States and Japan. After overcoming initial obstacles of the shape, consistency, binder, and attractiveness of the feed, we began present comparative studies of various formulations which make use of economical components. The feed presently used as our standard includes rice bran, shrimp meal, fish meal, soybean meal, algin, fish soluble, and lecithin. The formula for this diet is available to anyone wishing to use it as an experimental or control diet. Since growth on our best variations of this feed is still slower than that observed in nature at comparable temperatures, we still have a long way to go in describing the nutritional needs of shrimp. We have good evidence that the nutritional needs of shrimp change with successive life history stages, and the types of feed acceptable to animals in different stages are certainly different. One of the difficulties in studying nutritional needs is that we still must use live foods for the larval stages; no acceptable compounded feeds have been developed for these tiny shrimp.

The cost of ingredients in a feed is particularly important at this point since food conversion rates are poor with the diets presently in use. For this reason we have tried to make maximum use of ingredients which are waste products or at least inexpensive in the areas where shrimp are likely to be reared.

Juvenile shrimp searching for food on the bottom with their clawlike legs which have hairs sensitive to certain chemicals. Shrimp here are eating a standard extruded diet.

The role of diseases in shrimp mortality is not clear. In nature, diseases probably weaken some shrimp, making them easy prey of their many enemies. The extent to which this happens in seminatural rearing ponds is unknown. Some diseases have been observed, however, and as crowding increases with intensive culture practices more disease problems are anticipated.

Basic background histological studies of normal and diseased shrimp are underway in Galveston to aid in the recognition of diseases. In addition, diseases of shrimp from wild and cultured



Foods of various forms and textures are given shrimp at various stages in their life cycle. The flakes at right are fed to young postlarvae while older animals eat a similar food in a wormlike extruded form.

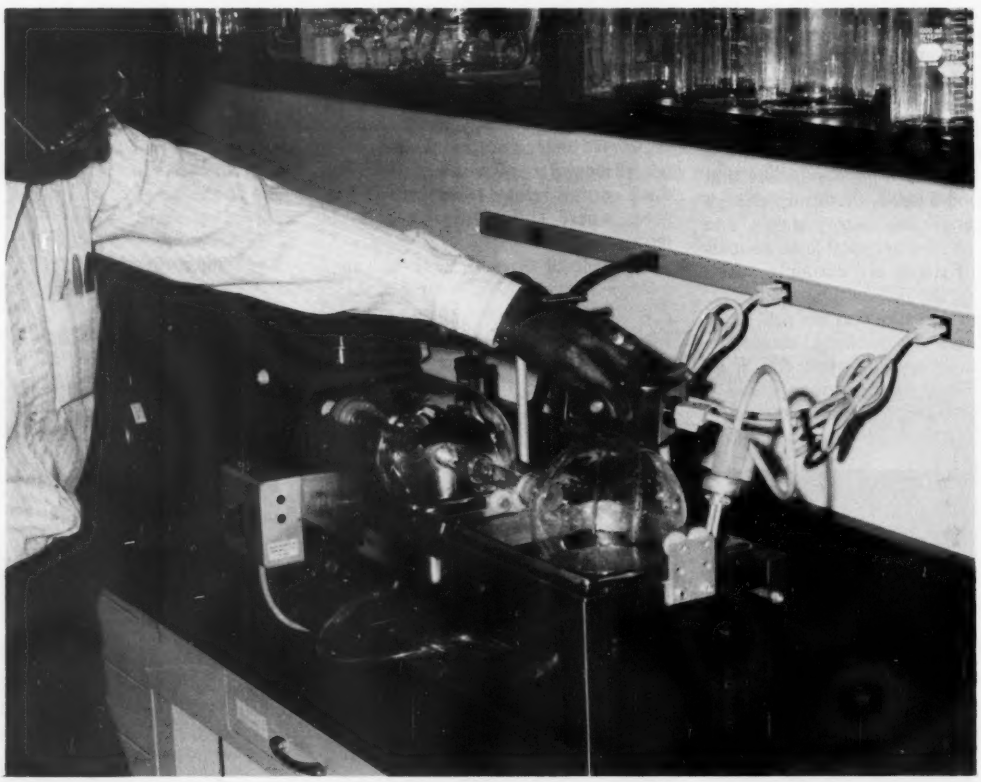
Experimental closed raceway system enclosed in a greenhouse to provide a controlled environment.

shrimp are being described. Methods of preventing and treating diseases are also being tested. The implementation of suitable techniques for preventing and controlling diseases should provide at least a partial solution to the poor survival of shrimp in ponds.

In addition to the biological and economic problems already discussed, the potential shrimp farmer has to overcome an additional set of problems in selecting a site. Difficulties such as the high cost of coastal land, pollution of or from an aquaculture operation and weather-related problems have led us to begin experimentation with systems offering more control than the seminatural open pond.

A closed raceway system is one of these systems which has been used successfully in prelimiary efforts to rear shrimp under very crowded conditions. The system has the advantage of being enclosed so that environmental control is possible, and predators and competitors are completely eliminated. Once the system has been filled, no more water enters or leaves the system until the shrimp are harvested so no pollution problems exist and disease control is simplified. Circulation and aeration are accomplished by air-lift pumps and waste removal methods used are techniques developed for treatment of sewage. The system when perfected may have applications in the culture of many fish and shellfish.

Profitable shrimp aquaculture is probably several years off and the "get-rich-quick" schemes many have dreamed of will probably remain only dreams; however, we do see some steady progress toward farming shrimp.



Fishery biologist using the rotary evaporator to concentrate steroid containing solutions for the isolation of shrimp hormones.

MFR Reprint 975. From Marine Fisheries Review, *Vol. 35, Nos. 3-4. Copies of this reprint, in limited numbers, are available from D83, Technical Information Division, Environmental Science Information Center, NOAA, Washington, DC 20235.*

Fresh shrimp for tempura can command upward of $10 a pound in Japan. An NMFS scientist reports on the culturing of this specialty.

Shrimp Culture in Japan

C.R. MOCK

C.R. Mock is a Fishery Biologist at the NMFS Gulf Coastal Fisheries Center, Galveston, Tex. This report is extracted from a longer paper that will appear in a forthcoming NMFS publication, "Proceedings of the First Joint Meeting, U.S.-Japan Aquaculture Panel." The meeting was held in Japan, October 14-29, 1971.

One of the most valuable marine species in Japan is the "Kuruma-Ebi" *(Penaeus japonicus)* shrimp fishery, which commanded a price of 7 to 30 U.S. dollars per kilogram in 1971 at the Tokyo Central Fish Market. Although this price is high compared with U.S. prices, it is due to the fact that the Japanese people demand live shrimp for the preparation of a delicacy known as tempura.[1]

Over the years much time has been spent developing methods of holding this species in ponds and rearing it to market size. Even though the Japanese have successfully reared shrimp through several generations, they explained that it was not economical to rear shrimp to sexual maturity because it was time-consuming and because the fecundity of the females was reduced. Therefore, gravid females are purchased directly from the commercial fishing fleets and then spawned.

Once the eggs have hatched, the water is fertilized to stimulate the growth of diatoms. Predetermined amounts of fertilizer and seawater are added each day to the tank until the larval shrimp have reached the last mysis stage. Brine shrimp nauplii *(Artemia* spp.) are fed from the last mysis stage through the fourth postlarval stage. The shrimp are then fed fresh meats of clams *(Venerupis philippinarum)* and mussels *(Mytilus edulis)*, which are crushed and distributed throughout the ponds. Because it is too costly and time-consuming to separate the crushed shell from the meats, the shell eventually covers the pond bottom, resulting in a substrate that hampers the burrowing of the shrimps. Thus, ponds must be drained or dredged periodically to remove the shell debris.

Although larval rearing techniques are primarily the same today as they were 10 years ago, research in shrimp culture has been expanded because of three important factors: (1) the rising demand and costs for fresh food items to be fed to the shrimp; (2) the rising wages of employees; and (3) disease problems encountered.

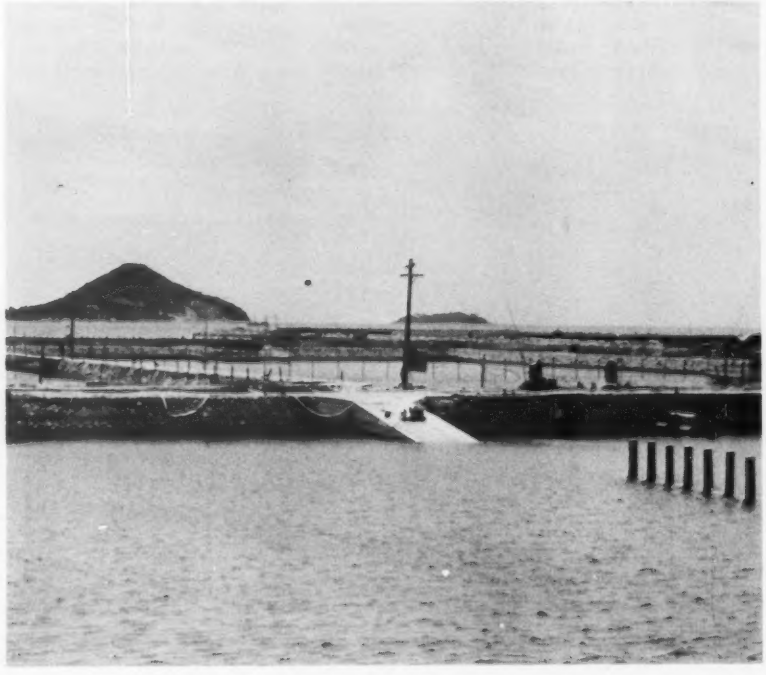
Of particular interest is the use of a by-product of soy sauce production, a cake which is ground into powder to fertilize the water. Not only does it stimulate the growth of diatoms, but the larval shrimp also eat it. As the shrimp grow in size, this powder is either extruded or pressed into a size suitable for

Metric tons of *Penaeus japonicus*.

YEAR	SOURCE		
	Cultured	Natural Catch	Imported
1964	154	3,184	17,087
1965	95	3,010	21,011
1966	211	2,479	36,156
1967	307	2,338	44,466
1968	311	1,884	32,204
1969	295	1,585	48,886

Shrimp farming ponds in Yamaguchi Prefecture, at the southern tip of Honshu, the principal island of Japan.

[1] Editor's note: Tempura is a method of cooking. Shrimp, other seafoods, chicken, fresh vegetables are dipped in batter and deep-fried. Recipes for the batter vary and are often a closely-guarded professional secret. Usually, foods cooked this way are served with a special sauce. It is popularly held that the technique was introduced into Japan by the Portuguese centuries ago. Tempura restaurants are a frequent and delightful feature of the Japanese scene.



Above and below.—Further views of shrimp farming ponds in Yamaguchi Prefecture.

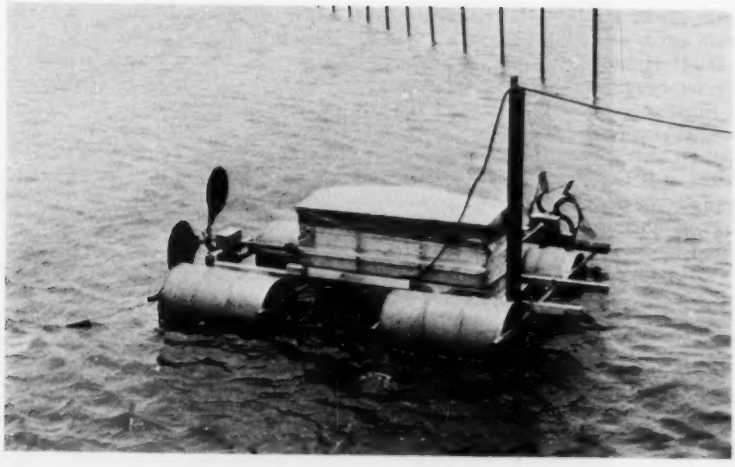
eating. At the Kagoshima Prefecture Fisheries Experimental Station, the Director, Dr. K. Shigeno, remarked that although the shrimp ate this artificial food and grew to market size, the consumer was not satisfied with the quality or color of the prawns. He felt that the problem was primarily a vitamin deficiency. Artificial foods with a variety of additives are being tested at Dr. Shigeno's laboratory.

Research is also being directed toward rearing prawns to market size in a closed system. A 1,000-cubic meter cement tank (23 m in diameter and 3 m deep) has been built at the Tarumizu Kagoshima Prefecture Fish Experiment Station. The water temperature can be controlled, and a false bottom with airlift pipes has been installed as an in-bottom filter. Twenty-day-old postlarval shrimp have been stocked in this tank and reared to market size with good results. However, during two recent experiments a number of problems occurred, resulting in poor production.

Circulation of the water mass within a rearing system was emphasized for either fish or shrimp culture. At Tarumizu Kagoshima Prefecture Fish Experimental Station the flow was maintained with water jets, while a large mechanical stirrer was being tested at Setonaikai Saibai Gyogyo Center, Tamano Jigyojo.

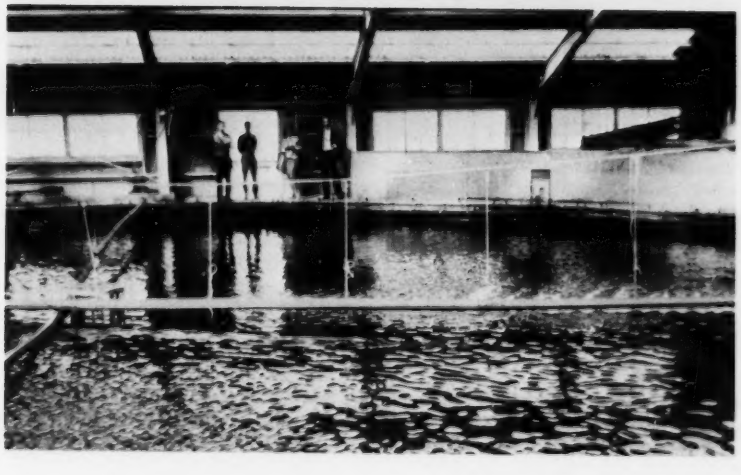
At the Nansei Regional Fisheries Research Laboratory, Dr. H. Kurata spoke about the natural waves of *Penaeus japonicus* postlarvae that enter the estuaries. Monitoring of these waves now indicates that recruitment is presently less than in previous years. The total tonnage landed by the commercial shrimp fleet is also down. Therefore, the concept of seeding the system with 1.2×10^8 20-day-old postlarval shrimp is being tested to see if the system is still a suitable environment, if production of shrimp can be stimulated, and if new areas can be used. Some shrimp are released directly into the nursery grounds, while others are placed in a pen (30 x 10 x 10 m) for 2 to 4 weeks to acclimate them to estuarine waters.

Dr. M. Fujiya, also of the Nansei Laboratory, began physiological studies to measure the "quality" of shrimp larvae reared in different ways, by observing their reaction to anesthetics. His approach is to insert electrodes into the



Floating raft with electrical agitator used to maintain circulation and desired oxygen levels in ponds.

Greenhouse used to house fish hatchery.



New experimental 1,000-ton tank (23 meters in diameter) for intensive culture of shrimp to market size.

brain of the shrimp and record their brain waves on an oscilloscope.

Dr. H. Hirata, at Kagoshima University, has begun work on the production of single-species mass cultures of diatoms and their preservation. At present, diatoms are concentrated and later frozen at 0°C. They can be held successfully for periods of 30 days or less. Various other techniques are now being tested.

At the University of Tokyo, School of Fisheries, Dr. Ogoaowara and Dr. T. Sano discussed the culture of freshwater shrimp of the species *Macrobrachium*. Eleven different species were being studied. To rear the larval stages, they indicated that a medium of 50 percent fresh water and 50 percent seawater was necessary. A diet of *Artemia*, reared on a freshwater culture of *Chlorella*, is fed during the larval stages along with ground clam (*Tapes* sp.) meat. When the shrimp are older, pieces of chicken egg shells are added to supplement the calcium in their diets.

Juveniles of *Macrobrachium rosenbergi* have been reared on commercial trout pellets to market size in 6 months at the Izu Branch Laboratory. Although results have been satisfactory, production costs were not made available.

Packing live shrimp for the market.

MFR Reprint 976. From Marine Fisheries Review, *Vol. 35, Nos. 3-4. Copies of this reprint, in limited numbers, are available from D83, Technical Information Division, Environmental Science Information Center, NOAA, Washington, DC 20235.*

Hauls in the southern U.S. shrimp fleet consist of shrimp, fishes, and other creatures. Here the shrimp are being sorted from a mixed catch taken off Florida.

Chitin Bibliography

An unexpected spinoff produced by the new water pollution laws is a bibliography on chitin and chitin derivatives. E.R. Pariser and S. Bock used a Massachusetts Institute of Technology Sea Grant Program seed grant to support preparation of an annotated bibliography of selected publications from 1965 to 1971 on the polymer chitin and its derivatives.

Information included in the compilation includes investigation into chitin's distribution, properties and uses.

Impetus for the bibliography came from the Federal government's pressures on the fishing industry to stop dumping lobster, shrimp and crab carcasses, which are primarily chitin, into the ocean—the industry's traditional disposal method. Chitin resists biodegradation and is thus a source of visual and biological pollution.

The rulings meant that unless the industry could find new ways for chitin disposal—or better, new uses for the "wastes"—many of the smaller processors would be forced out of business because they could not afford expensive disposal alternatives.

Despite its abundance, chitin has aroused minimal scientific and no real commercial interest. The polymer is difficult to harvest, isolate and purify. Almost no economic incentive existed prior to the pollution legislation to prompt a systematic, in-depth study.

Chitin derivatives have many potential uses, including: in pharmaceuticals; in paper and on it, to increase its wet strength and to improve its printing surface, respectively; in water purification processes as a coagulant; in agriculture, mixed with insecticide (since it resists biodegradation, it would provide long-term time release effectiveness on the insecticide).

Several billion tons of chitin are produced each year by marine copepods, and these are only one of the many animal groups that synthesize the polymer as an important exoskeleton component. Insects, crustacea, some of the annelids, the molluscs, other of the invertebrates, and even some cephalochordates synthesize chitin. Many fungi, possibly even some bacteria, have chitin in their cell walls, where it appears to replace cellulose.

Source: Sea Grant 70's, Vol. 3, No. 5, Jan. 1973

Shrimp Yield of 4 Tons Per Acre Claimed

Intensive culture methods at the Kanda Fish Farm in Japan have resulted in yields as high as 10 tons per hectare per year (in English units, more than 4 tons per acre), according to a scientific paper published in Taiwan, Republic of China.

The paper, in Chinese with an English abstract, is written by Ting-Lang Huang, Tainan Fish Culture Station, Taiwan Fisheries Research Institute, and Shumei Kanda, Kanda Shrimp Farm. It appeared in the publication *Aquiculture*, Vol. 2, No. 1, June, 1972. The publication is issued by the Tungkan Marine Laboratory, Taiwan Fisheries Research Institute, Taiwan, Republic of China.

The shrimp in question is *Penaeus japonicus*, commonly used for culture in Japan.

Large penaeid shrimp taken by bottom trawling in the Hawaiian Islands.

NMFS Aids Shrimp Studies in States

Through grants-in-aid, NMFS has provided Federal monies to seven of the States to conduct research studies on shrimp. Such studies permit the States to carry out work of mutual interest that could not otherwise be funded.

Such work is done (not only on shrimp, but many other fisheries subjects) under three separate acts of Congress. These are P.L. 88-309, the Commercial Fisheries Research and Development Act of 1964 as amended; P.L. 89-304, the Anadromous Fish Act of 1965 as amended; and P.L. 89-720, the Jellyfish Act of 1966 as amended.

Details of the work are given in the NMFS publication, "Grant-in-Aid for Fisheries Program Activities, 1972," prepared by the Grant-in-Aid staff, principal contributor, Paul R. Nichols.

Work on shellfish has consisted of 89 projects funded at a total cost of about $9 million, with emphasis on oyster and shrimp research. Of the projects funded, 63 have been completed and 26 are continuing.

The shrimp projects are:

Alaska

Chief Investigator: Jerry McCrary

Pandalid shrimp studies—Data were collected for detailed description of the life histories of the pink shrimp, sidestripe shrimp, coonstripe shrimp, hump shrimp, and other species if feasible in the Kodiak-eastern Alaska regions. Seasonal geographic distribution, migration pattern, and variations in abundance of these shrimp were investigated also.

(Project Completed 1972)

Georgia

Chief Investigator: Charles M. Frisbie

Seasonal abundance and biological stability of the commercial shrimp of Georgia—Sampling stations were located offshore in sound, rivers, and in marshes thoughout the shrimps' habitat. Trawl, seine, and plankton net collected adults, postlarval, and larval shrimp throughout the year. Determinations were made on relative and seasonal abundance, growth rate, sex ratio, spawning success, and limiting environmental factors of shrimp.

(Project Completed 1969)

Georgia

Chief Investigator: Clifford J. Knowlton

Preliminary studies of a potential finfish industry from commercial shrimp landings—The purpose of this study was to determine the species composition and marketable size of finfish in commercial shrimp catches and their relative abundance during the commercial shrimping season.

(Project Completed 1971)

Louisiana

Chief Investigator: J. G. Broom

Coastwide study of penaeid shrimp—The life history of the commercial important species of penaeid shrimp in estuary waters was studied to provide information for improved management of these resources including a coordinated effort through the Gulf State Marine Fisheries Commission.

(Project Completed 1968)

Louisiana

Chief Investigator: Wilson J. Gaidry

Investigations of commercially important penaeid shrimp in Louisiana's estuaries—

Causes of seasonal fluctuations and abundance in shrimp populations in the estuaries are studied to determine how changes in the estuarine environment affect annual and continued production.

(Project Continuing)

Maine

Chief Investigator: Ronald G. Rinaldo

Northern shrimp—biological and technical research—Studies were made on waters adjacent to the Maine coast to determine the relative abundance of species of northern shrimp, particularly *Pandalus borealis*, and life history and seasonal availability of the several species. Technical problems associated with economical and efficient harvesting and marketing these species were also investigated.

(Project Completed 1970)

Maine

Chief Investigator: Ronald G. Rinaldo

Northern shrimp—assessment of some population parameters—This project is designed to establish shrimp population parameters by sampling and enhancing the collection, catch, and data from survey cruises.

(Project Continuing)

Mississippi

Chief Investigator: J. Y. Christmas

Investigation of commercial important penaeid shrimp in Mississippi estuaries—Under this project a study is made of the environmental requirements and relationships of penaeid shrimp with special reference to variations in commercial catch in an attempt to improve predictions of the availability of shrimp to the fishery.

(Project Continuing)

North Carolina

Chief Investigator: Edward G. McCoy

Shrimp studies—Information was obtained on population dynamics, including migratory behavior, for pink, brown, and white shrimp marked with biological stains and fluorescent pigments and released in nursery areas tributary to Core Sound and Lower Cape Fear River estuaries. A combined total of 26,989 shrimps were marked and released, of which 1,671 or 6.2 percent were recaptured. Mark and recapture studies on brown shrimp were conducted in Pamlico Sound and Bogue Sound estuaries, including Newport River.

(Project Completed 1969)

North Carolina

Chief Investigator: Edward G. McCoy

Studies of commercial penaeid shrimp—This study is undertaken to determine the effect on the resulting commercial catch when pre-commercial-size pink shrimp are harvested and discarded while fishing for commercial-size brown shrimp.

(Project Continuing)

Oregon

Chief Investigator: Gary Milburn

Study on the distribution and abundance of pink shrimp, Pandalus jordani, in the Pacific Ocean off Oregon—Sampling of commercial pink shrimp landings at Warrenton, Newport, and Coos Bay has been completed. Length-frequency, catch, and effort data by area of catch were reported. The vertical distribution and migratory behavior of this species by diel, lunar, and seasonal periods, and the environmental factors which may influence these movements were investigated off the Oregon coast near Astoria and Newport.

(Project Completed 1970)

Oregon

Chief Investigator: Robert Loeffel

An evaluation of methods for determining movements of shrimp—This study was twofold: (1) to evaluate the feasibility of various techniques of determining the movements of Pacific pink shrimp, and (2) to develop holding and rearing techniques of pink shrimp in aquaria.

(Project Completed 1971)

Texas

Chief Investigator: Gary M. Stokes

The population and distribution of penaeid shrimp in Lower Laguna Madre—The purpose of this study is to determine the population and distribution of juvenile penaeid shrimp in Lower Laguna Madre and its watershed with relation to ecological factors, and conduct a brief survey of the bait shrimp fishery in the Lower Laguna Madre in preparation for future studies dealing with the relationship between juvenile production in the Lower Laguna Madre, the bait fishery, and commercial production in the Gulf of Mexico.

(Project Continuing)

NMFS Publications on Shrimp, 1970-72

A number of scientific reports on shrimp have appeared in recent NMFS publications. All are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC, 20402. An alphabetical list, by author, follows:

Abramson, Norman J., and **Patrick K. Tomlinson,** "An application of yield models to a California ocean shrimp population," Fishery Bulletin, Vol. 70, No. 3, p. 1021-1041.

ABSTRACT

Two types of yield models were utilized to analyze fishery data from California's northern-most bed of ocean shrimp, *Pandalus jordani*. The Schaefer form of stock production model was applied to catch and effort data for the years 1954 through 1969. Age-structured catch data for 1955 through 1968 were analyzed by the Murphy method to obtain mortality rates and biomass estimates. Catchability coefficients and a growth curve were also estimated. Attempts to fit spawner-recruit models to estimates obtained from the age-structured catch data were inconclusive; so, age specific mortality and growth estimates were only used to fit a yield-per-recruit model.

After comparing the results from the two models, the Schaefer model was deemed most suitable for managing this fishery. The model estimated the maximum sustainable yield at 2.46 million pounds. A strategy for managing the fishery under a quota system was proposed.

Anderson, William W., "Contributions to the life histories of several penaeid shrimps (Penaeidae) along the south Atlantic coast of the United States." U.S. Fish and Wildlife Service, Special Scientific Report—Fisheries No. 605, May 1970, iii+24 p., 15 figs., 12 tables.

ABSTRACT

Shrimp, the most valuable fishery resource of the south Atlantic coast of the United States, contributed about 40 percent of the $27 million exvessel value of all fishery landings in the area in 1966. Three species of shallow-water penaeid shrimps are of greatest commercial importance: white shrimp, *Penaeus setiferus;* brown shrimp, *P. aztecus;* and pink shrimp, *P. duorarum*. The shrimp fishery is reviewed for trends in yield for the area as a unit, by States, and by species, for the 10-year period 1958-67. A trend toward steady decline in total shrimp landings is indicated. During studies on the white shrimp along the south Atlantic coast of the United States in 1931-35, data were obtained on the brown shrimp; the sea bob, *Xiphopeneus kroyeri;* and *Trachypeneus constrictus*. Observations were also made on the pink shrimp from operations of the Bureau of Commercial Fisheries R/V

Oregon of northeast Florida near Cape Kennedy in 1965-67. This report presents size distribution, ovary development, and sex ratios of the several species of shrimp, and includes limited information on spawning season.

Anonymous, "Report of the National Marine Fisheries Service Gulf Coastal Fisheries Center, fiscal years 1970 and 1971." NOAA Technical Memorandum NMFS SER-1, July 1972, iii+26 p., 14 figs., 4 tables.

ABSTRACT

Progress is reported at the National Marine Fisheries Service Gulf Coastal Fisheries Center (formerly the Biological Laboratory, Galveston, Texas). Emphasis is placed on shrimp, and the research involves the fields of mariculture, population dynamics, ecology, and oceanography.

Barr, Louis, "Alaska's fishery resources—the shrimps." U.S. Fish and Wildlife Service, Fishery Leaflet 631, January 1970, iii+10 p., 7 figs., 1 table.

ABSTRACT

Shrimp fishing began in Alaska over 50 years ago. Recently the annual domestic catch has been as high as 40 million pounds. Japanese and Soviet Union fishermen operating in Alaska waters have caught as much as 70 million pounds annually in recent years.

The five commercially important shrimp of Alaska belong to the family Pandalidae; the most important is the pink shrimp, *Pandalus borealis.* The complicated life histories of these shrimp are all similar. The shrimp develop first as males and after several years transform to females, which they remain for the rest of their lives.

United States fishermen use otter trawls, beam trawls, and pots, and deliver their catch to ports in Alaska; foreign fishermen use larger otter trawls and process the catch at sea.

The Alaska Department of Fish and Game and the Bureau of Commercial Fisheries are studying shrimp. They are sampling the commercial catch, trying to improve the product, and conducting exploratory fishing and biological research.

Caillouet, C.W., Jr., B.J. Fontenot, Jr., W.S. Perret, R.J. Dugas, and **H.F. Hebert,** "Catches of postlarval white shrimp *Penaeus setiferus* (Linn.), and brown shrimp, *P. aztecus,* Ives, and temperature and salinity observations in Vermilion Bay, Louisiana, March 1963 to April 1967." U.S. Dep. Commer., NOAA, NMFS, Data Report 64, July 1971, 39 p. on 1 microfiche. $0.95.

ABSTRACT

A small trawl towed in a semicircle of 30.5-m (100 ft) radius in the shallow water near the shoreline was used to collect postlarval white shrimp and brown shrimp. Dates and hour of sampling, catches of postlarvae, species composition and subsamples of the catches, and water temperature and salinity data are presented.

Condrey, Richard E., James G. Gosselink, and **Harry J. Bennett,** "Comparison of the assimilation of different diets by *Penaeus setiferus* and *P. aztecus.*" Fishery Bulletin, Vol. 70, No. 4, p. 1281-1292.

ABSTRACT

Juvenile penaeid shrimp showed high and comparable assimilation efficiencies (80-85%) on a variety of plant and animal diets. In general assimilation efficiencies for proteins and lipids were consistently high; for carbohydrates, low. Organic assimilation per gram organic weight of white shrimp, *Penaeus setiferus,* proceeded at 3.7 mg hr^{-1} on an axenic diatom and 8.4 mg hr^{-1} on an artificial diet. The assimilation efficiency was lower for shrimp feeding on the algal mat coating *Spartina alterniflora* than on two components of the mat. Feeding mechanisms and probable natural diets are discussed as a basis for further study.

Cook, Harry L., and **M. Alice Murphy,** "Early developmental stages of the brown shrimp, *Penaeus aztecus* Ives, reared in the laboratory." Fishery Bulletin, Vol. 69, No. 1, p. 223-239.

ABSTRACT

The larval and first postlarval stages of the brown shrimp, *Penaeus aztecus* Ives, reared from eggs spawned in the laboratory, as well as the eggs themselves, are described and illustrated. The larvae and first postlarva are compared with those of the pink shrimp, *P. duorarum* Burkenroad, and white shrimp, *P. setiferus* (Linn.).

Corbett, Michael G., "Machine for separating northern shrimp, *Pandalus borealis,* from fish and trash in the catch." Fishery Industrial Research, Vol. 6, No. 2, May 1970, p. 53-62, 8 figs.

ABSTRACT

Because of the labor required in separating northern shrimp from the unwanted components of the catch that are taken along with it, this valuable resource in the Gulf of Maine is not harvested to the extent possible. Consequently, a machine was developed to separate the shrimp from the bulk of groundfish and other species taken in trawl catches during exploratory and commercial fishing. Its use eliminates the laborious task of sorting the catch by hand, yet the separator recovers about 95 percent of the shrimp that are fed into it, while eliminating about 90 percent of the trash.

Ellis, James E., "The use of electricity in conjunction with a 12.5-meter (headrope) Gulf-of-Mexico shrimp trawl in Lake Michigan." NOAA Technical Report NMFS SSRF-653, March 1972, iv+10 p., 11 figs., 4 tables. $0.25.

ABSTRACT

The catching efficiency of a 12.5-meter standard shrimp trawl and the same trawl fitted with three different electrode array systems with power on and power off was investigated.

The standard trawl caught 1.54 times or 54.2% more kilograms of fish than the electrode-equipped trawl with power off. The electrode array hanging across the mouth area of the trawl acted as a visual stimulant and thus reduced the trawl's catch rate.

Overall the electrical trawl with power on caught 1.19 times or 19.0% more kilograms of fish than the electrical trawl with power off. Array 2 with power on had the best catch rate—1.86 times or 86.9% more kilograms of fish than the power off catch rate. The avoidance of fish to an electrode array was more than offset with the catch rate of array 2 with power on. The dominance patterns of the catches with each system tested did not change significantly with the exception of chub catches with array 2 with power on.

Length selectivity was highly significant for chubs caught with arrays 2 and 3 with power on. No significant length selectivity occurred with the other species landed.

Emiliani, Dennis A., "Equipment for holding and releasing penaeid shrimp during marking experiments." Fishery Bulletin, Vol. 69, No. 1, p. 247-251.

(NO ABSTRACT)

Fontaine, Clark T., "Conversion tables for commercially important penaeid shrimp of the Gulf of Mexico." U.S. Dep. Commer., NOAA, NMFS, Data Report 70, December 1971, 9 p. on 1 microfiche. $0.95.

ABSTRACT

Tables are divided by classifications commonly used by the industry to designate landings of whole or headless brown *(Penaeus aztecus),* white *(P. setiferus),* and pink *(P. duorarum)* shrimp. Data presented by sex and sexes combined for each species include shrimp that range from 70 to 235 mm total length.

Fontaine, C.T., S.E.P. Gislason, and **W.L. Trent,** "A system for collecting large numbers of live postlarval shrimp." Fishery Bulletin, Vol. 70, No. 4, p. 1298-1302.

(NO ABSTRACT)

Hudson, J. Harold, Donald M. Allen, and **T.J. Costello,** "The flora and fauna of a basin in central Florida Bay." U.S. Fish and Wildlife Service, Special Scientific Report—Fisheries No. 604, May 1970, iii+14 p., 2 figs., 1 table.

ABSTRACT

One hundred ninety-six species of plants and animals are reported from a nursery area for pink shrimp, *Penaeus duorarum duorarum,* in a basin of central Florida Bay. Many of the organisms are benthic and associated with shallow beds of turtle grass, *Thalassia testudinum.* Although abrupt habitat variations may affect species distribution, the general distribution of organisms in the basin and bay defines environments influenced by different water masses.

Kelly, Carolyn E., and **Anthony W. Harmon,** "Method of determining carotenoid contents of Alaska pink shrimp and representative values for several shrimp products." Fishery Bulletin, Vol. 70, No. 1, p. 111-113.

ABSTRACT

An extraction method is described for estimating the amount of carotenoids in pink shrimp. The carotenoid index is useful as a measure of quality and as an indicator of changes during storage. Values for several shrimp products are reported.

Love, Travis D., Mary H. Thompson, and **Melvin E. Waters,** "Report of the National Marine Fisheries Service Fishery Products Technology Laboratory, Pascagoula, fiscal years 1970 and 1971." NOAA Technical Memorandum NMFS SER-3, June 1972, iii+12 p., 7 figs., 4 tables.

(NO ABSTRACT)

Miller, George C., "Commercial fishery and biology of the freshwater shrimp, *Macrobrachium*, in the lower St. Paul River, Liberia, 1952-53." U.S. Dep. Commer., NOAA, NMFS, Special Scientific Report—Fisheries No. 626, February 1971, iii+13 p., 8 figs., 7 tables.

ABSTRACT

A small fishery was conducted for the large commercial fresh-water shrimp, *Macrobrachium vollenhovenii*, using traps. A second smaller species, *M. macrobrachion*, was culled from the trap catch for the fishermen's use. The estuarine fishery was seasonal (May to January), during the period of low salinity. Cost of raw tail meats to the consumer was over $1.00 (U.S.) per pound. The fishermen derived more than $7,500 from the fishery.

Commercial shrimp, *M. vollenhovenii*, spawned in the estuary from May to January. Fecundity was estimated at 12,000 to 45,000 eggs per female. As the embryo developed the color of the egg changed from red to brown. Embryonic and larval development to time of setting of *M. vollenhovenii* was believed similar to that of *M. rosenbergii*, 50 to 65 days. An intensive push-net fishery was conducted by women on the zero age group soon after the juveniles had set. Juvenile shrimp were not caught by traps. Monthly length distributions indicated that the fishery was supported by age group one, which was replaced at the end of the season by age group zero. Age group zero grew rapidly and reached a modal length of 75 to 80 mm. in 9 months in January; and adults grew slowly and increased in length to 85 to 90 mm. in May, and 100 to 105 mm. in November. The weight-length relation of *M. vollenhovenii* ovigerous females was expressed by the equation Log W = −4.656603 + 3.011392 Log L, and males and nonovigerous females by Log W = −4.829560 + 3.092213 Log L.

The characters used to distinguish *M. macrobrachion* from the commercial shrimp are given. The smaller species (modal length 50 to 54 mm.), constituted 88 percent of the shrimp discarded from the commercial catch. The trap fishery harvested the adults of the two species, which differed considerably in length, without harm to either species.

Miller, Morton M., and **Darrel A. Nash,** "Regional and other related aspects of shellfish consumption—some preliminary findings from the 1969 consumer panel survey." U.S. Dep. Commer., NOAA, NMFS, Circular 361, June 1971, iv+18 p., 21 figs., 3 tables, 10 apps.

ABSTRACT

A consumer survey panel, consisting of representative households throughout the United States, recorded their fishery product purchases for a 12-month period, beginning in February 1969. They were participants in a study conducted under the aegis of the National Marine Fisheries Service, Division of Economic Research. This paper deals mainly with study findings respecting the consumption of major species of shellfish, at home and away from home.

Findings of the study indicate marked regional preferences for individual shellfish items. For example, oysters are consumed in South Atlantic States at nearly double the national per capita rate. Similarly, clams enjoy a high rate of consumption in Middle Atlantic and New England areas. All of which suggests an important correlation between consumption and tradition as well as a persistent tendency for seafood varieties, particularly those consumed in a "fresh" form, to be consumed in the area of catch.

The study also indicated an association between high income households and shellfish consumption, with oysters a single notable exception. Age of consumer, too, has an apparent bearing on shellfish consumption as it was found that older consumers are the more disposed toward consumption of these products.

With respect to consumption away from home, it appears that half or more of the crabs and lobsters are consumed in meals outside the home, but the majority consumed of other products was at home.

Pérez Farfante, Isabel, "A key to the American Pacific shrimps of the genus *Trachypenaeus* (Decapoda, Penaeidae), with the description of a new species." Fishery Bulletin, Vol. 69, No. 3, p. 635-646.

ABSTRACT

Study of American Pacific members of the genus *Trachypenaeus* reveals that variation in armature of the telson includes not only movable spines, but also fixed spines and even no spines at all. It also confirms that the eighth somite bears two arthrobranchiae instead of one arthrobranchia and one pleurobranchia. A new species, *Trachypenaeus fuscina*, is described, the specific features of *T. faoea* Loesch and Avila are presented, and a key to the five members of the genus occurring in the region, together with their ranges, is included.

Pérez Farfante, Isabel, "Diagnostic characters of juveniles of the shrimps *Penaeus aztecus aztecus, P. duorarum duorarum,* and *P. brasiliensis* (Crustacea, Decapoda, Penaeidae)." U.S. Fish and Wildlife Service, Special Scientific Report—Fisheries No. 599, February 1970, iii+26 p., 25 figs.

ABSTRACT

Illustrated tables are presented for the identification and sex determination of juveniles (with carapace lengths of 8 mm or more) of three grooved shrimps of the genus *Penaeus* occurring in various areas along the North American Atlantic coast, in the Gulf of Mexico, and in the Bermudas. Included is an account of the development of the petasmata, thelyca, and appendices masculinae.

Sick, Lowell V., James W. Andrews, and **David B. White,** "Preliminary studies of selected environmental and nutritional requirements for the culture of penaeid shrimp." Fishery Bulletin, Vol. 70, No. 1, p. 101-109.

ABSTRACT

Types of substrate, type of aeration, and stocking density were compared as prerequisites for high-density culture studies with penaeid shrimps. Neither sand-shell substrate nor brick subdivisions of culture tank bottoms produced significantly higher survival rates than bare fiber glass tanks. Forced air supplied via airstones proved to be a more suitable form of aeration than did physical agitation of the water column in culture tanks by high-pressure nozzles. Survival rates of 80 to 90% were achieved when biomass densities did not exceed 40 g/m^2.

Semipurified pelleted diets (i.e., containing defined chemical ingredients plus one or more natural products) having a complement of nutrients including minerals and vitamins, various ratios of shrimp to fish meal, protein hydrolysates, and such diets fed at three percentages of total biomass daily were compared for their ability to produce increases in growth. Diets without fish or shrimp meal sustained biomass while those diets having the highest proportion of shrimp to fish meal in addition to added vitamins produced over 60% increase in total biomass over a 3-month period. Animals fed a combination of yeast, soy, and casein hydrolysates increased 39% in biomass over the same period of time while those fed each of the above hydrolysates during the 3-month period separately showed only an average of 18% increase in weight. Feeding shrimp with a fish-shrimp base with added vitamins at a rate of 15% daily of the total biomass produced a 164% increase in weight with 95 to 100% survival during the 3-month period. Using semipurified pelleted diets, a food conversion ratio of 5.5 was obtained.

Establishing selected preliminary environmental and nutritional requirements for penaeid shrimp resulted in the successful and reproducible production of major biomass increases with relatively high survival rates and low food conversion ratios.

—Compiled by Lee C. Thorson

Editor's Comments

On Eating Shrimp, and Some Other Matters

Except in the metaphorical, derogatory sense ("a little shrimp of a man"), which, according to the Oxford English Dictionary, was being used as early as the 14th century by Chaucer, shrimp has not made much impress on English literature.

The minor poet, Michael Drayton (1563-1631) mentions the seafood in his magnum opus, *Poly-Olbion,* an immensely long versified guidebook to Jacobean England:

> The *Scallop* cordiall judgd, the dainty *Wilk* and *Limp*, The *Periwincle*, *Prawne*, the *Cockle*, and the *Shrimpe*. For wanton womens tasts, or for weake stomachs bought.

Shrimp is so universally popular that there must be literally thousands of recipes for its use. My own favorite contains one ingredient that I believe may be unique.

In the old days, in New Orleans, the recipe went like this:

> A lot of fresh shrimp from the French Market.
> Tap water.
> Salt.
> A bay leaf or two.
> Cloves.
> Other spices, according to the cook's whim.
> One copy of yesterday's *New Orleans Times-Picayune.*

I have forgotten just how the shrimp was cooked: whether it was thrown brusquely into boiling water or eased into cold water that was then brought to a boil: I seem to remember two antagonistic schools of thought about this.

When the shrimp were properly pink and done, it was served on a table spread with the *Times-Picayune* and the banquet was eaten, of course, with the fingers. The only accompaniments consisted of long warm loaves of French bread, butter, hot sauce for the few not content with the incomparable flavor of the shrimp itself, and icy beer. It would be ungentlemanly to state that there were "wanton women" present, but of "weake stomachs" there were none, for the rule of thumb was to buy about twice as much shrimp as one thought the specified number of guests could eat, and none ever went to waste.

In memory, at least, the bottom layer of the shrimp was the best of all, for the printer's ink of the *Times-Picayune* had not only stained the crisp shells but also permeated them and given to the shrimp itself a flavor most unusual.

One supposes that in the decades since those days, advances in printing technology have come up with an ink faster-drying and less penetrating. I rather hope not: *Times-Picayune*-flavored shrimp had a tang that was subtle and unique.

Every profession and trade, from the most exalted to the lowliest, has its own jargon. Marketing is no exception. I have been reading about "institutional" markets for a good many years and thought the term rather forbidding—bringing to mind standing in chow lines in the Army—until, in the preparation of this number of *Marine Fisheries Review,* I discovered it included restaurants. Now some restaurants are institutions in the common and more laudatory sense of the word, but it had not occurred to me that to our Marketing people they were a part of the "institutional" market. Makes it seem less formidable, somehow.

What is the most expensive edible fisheries product in the world? At my supermarket, Iranian caviar is selling for about a dime a gram, or over $40 a pound. As an upcoming *Marine Fisheries Review* article will show, in Japan elvers (eel larvae) can sometimes command hundreds of dollars a pound. Descending from these astronomical figures, one still finds some fairly high prices: it is not extraordinary, in Hawaii, toward New Year's, to pay $10 a pound for fresh tuna for sashimi. And as C. R. Mock points out in his article in this number, live shrimp for the tempura market in Japan regularly bring $10 or $15 a pound. Of course, one non-edible fisheries product has them all beat. High-quality cultured 8.5 millimeter pearls, made into necklaces, come to a cool $40,000 a pound or so.

With this number of *Marine Fisheries Review,* the publication has been moved to Seattle, where it joins the group of NMFS scientific publications, including the *Fishery Bulletin* and *Marine Fisheries Abstracts,* put out there by the NMFS Scientific Publications Staff. *Marine Fisheries Review* is in its 35th year of publication. It has always had a wide readership among the many constituencies that comprise the "fisheries audience." As in the past, it will continue to bring news notes and formal scientific articles dealing with the fisheries. It will be a medium for presenting fishery information in more detail, and usually more technically, than is possible in the dailies and the trade press. It will publish papers longer than can be accommodated in the latter. George B. Gross's fine paper on the shrimp fisheries of Latin America, in this number, is an example.

From time to time, a number of *Marine Fisheries Review* will be devoted to a single topic, as this one is to shrimp.

One new feature of *Marine Fisheries Review* will be a section called "Research Notes." This section will consist of short scientific papers announcing preliminary results of investigations which the authors wish to place upon the record as soon as possible. Reuben Lasker, NMFS Scientific Editor, has volunteered to serve as editor of this section. The papers will be refereed by experts. We hope to provide the authors with publication within about two months of acceptance.

A large number of people, both inside and outside of NMFS, have had a hand in the preparation of this number of *Marine Fisheries Review.* They have worked at short notice and with impossible deadlines—which they have somehow managed to meet. The list is too long to name them all, but I would like particularly to mention two former editors of *Marine Fisheries Review* for whose cooperation, courtesy, and good suggestions I am most grateful. They are Joseph E. Pileggi and Edward Edelsberg. I thank them both.

T.A.M.

☆ G.P.O. 797-340

NOTE

As this number of Marine Fisheries Review *was being prepared, final estimates for 1972 shrimp landings and values were not complete. Thus the figures reported for 1972 landings and values may not agree. The percentage differences will be found to be quite small.*